CS-61-047
December 1961

CONVAIR JET AIRLINERS

880M

990

GENERAL DYNAMICS | CONVAIR

CS-61-047
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CONVAIR 880M / 990 JET AIRLINERS

FOREWORD

The information presented in this volume is a compilation of articles previously published in the Convair Traveler. It is offered as a convenient source of reference on the 880M and 990 jet airliners. The appropriate Convair Manuals should be consulted to obtain the latest authoritative data. In instances where "880" is mentioned, "880M" is implied.

GENERAL DYNAMICS | CONVAIR

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SERVICE PUBLICATIONS SECTION

TABLE OF CONTENTS

THE CONVAIR 880 JET AIRLINER

The Convair 880M jet airliner is a medium range airplane with long range capabilities. This airliner, with its sister-ship, the Convair 990, are the two fastest jet airliners in the world.

The "880" is powered by four General Electric CJ805-3B turbojet engines equipped with sound suppressors and thrust reversers, permitting operation from present day airports designed for propeller-driven aircraft.

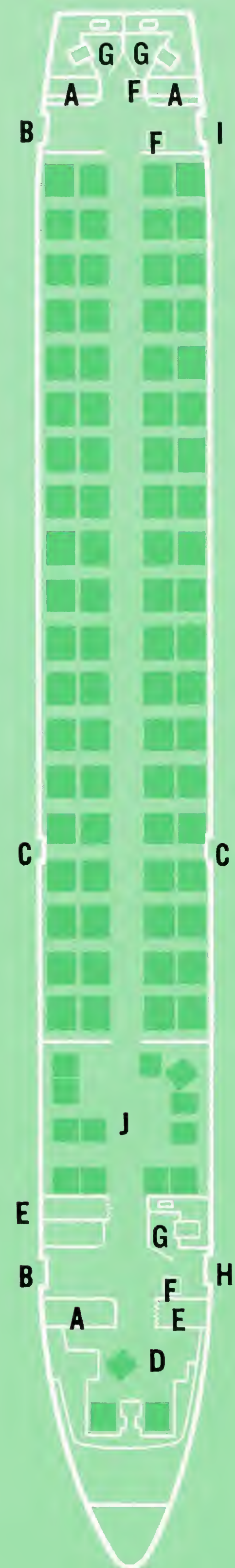
The "880" interiors are designed for a wide variety of seating arrangements. The seating configuration can be readily converted from first-class to combinations of first class and tourist accommodations, thus offering airline operators a versatility and flexibility never before available.

Direct operating costs over route segments of 1500 statute miles or longer are the lowest of any airplane in its class.

CONVAIR 880 INTERIORS
(TYPICAL)

TYPICAL SECTION WITH
STANDARD SEATING

TYPICAL SECTION WITH
COACH SEATING



FIRST-CLASS SEATING ARRANGEMENT — 88 PASSENGERS

ALL-COACH SEATING ARRANGEMENT WITHOUT FWD RH BUFFET AND COAT CLOSET
110 PASSENGERS — 5-ACROSS SEATING

A BUFFET
B SERVICE DOOR-EMERG. EXIT
C EMERGENCY EXIT
D PILOT COMPARTMENT
E COATS
F STEWARDESS
G LAVATORY
H MAIN ENTRANCE-FWD
I MAIN ENTRANCE-AFT
J CLUB AREA

The Convair 880 cabin is readily convertible from first-class to tourist seating and combinations of first-class and tourist seating arrangements. These arrangements offer airline operators a versatility and flexibility of operation never before available.

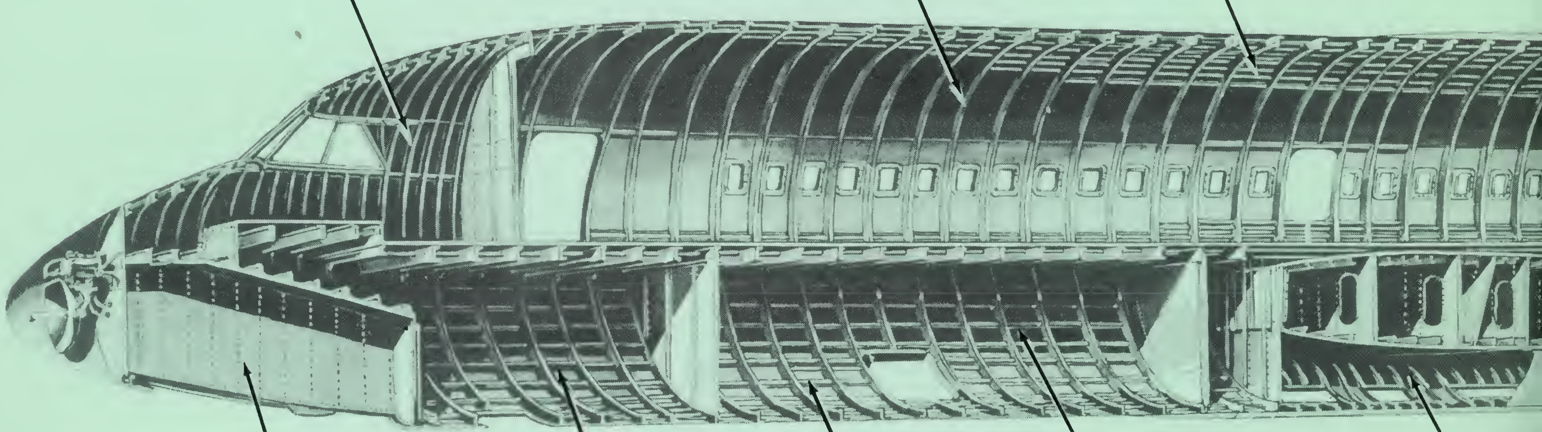
Design objective has been to create interesting groupings in the passenger cabin and to avoid the "tunnel" effect sometimes seen in conventional airplanes. This has been achieved by varying the ceiling levels to compartmentalize the passenger cabin without the use of partitions. To further enhance interior decor, and to create a feeling of division, each alternate block of three rows of seats is upholstered in a shade of contrasting or harmonizing color. This conforms to the grouping achieved by the varying ceiling levels.

The cabin may also be divided by inserting coat-closet dividers at any of six points, according to seating arrangement required for a particular flight. A club compartment, accommodating 12 persons, adds to the overall feeling of spaciousness, yet requires no more area than does conventional seating.

Luxury plus comfort were designed into the interiors by nationally-known industrial designers and stylists. Advanced sound-proofing techniques were developed to further enhance the smooth quiet flight of the Convair 880.

Indirect lighting, from fluorescent coves in the ceiling, tends to compartmentalize the area. There is additional indirect lighting at panels above each pair of windows. Windows, instead of being curtained, are equipped with tinted glass to filter the brighter sunlight encountered at altitudes seven miles above the earth. In addition, complete outside light may be eliminated by glare shield controls or shades at each individual window.

STRUCTURAL DETAIL OF THE 880 FUSELAGE

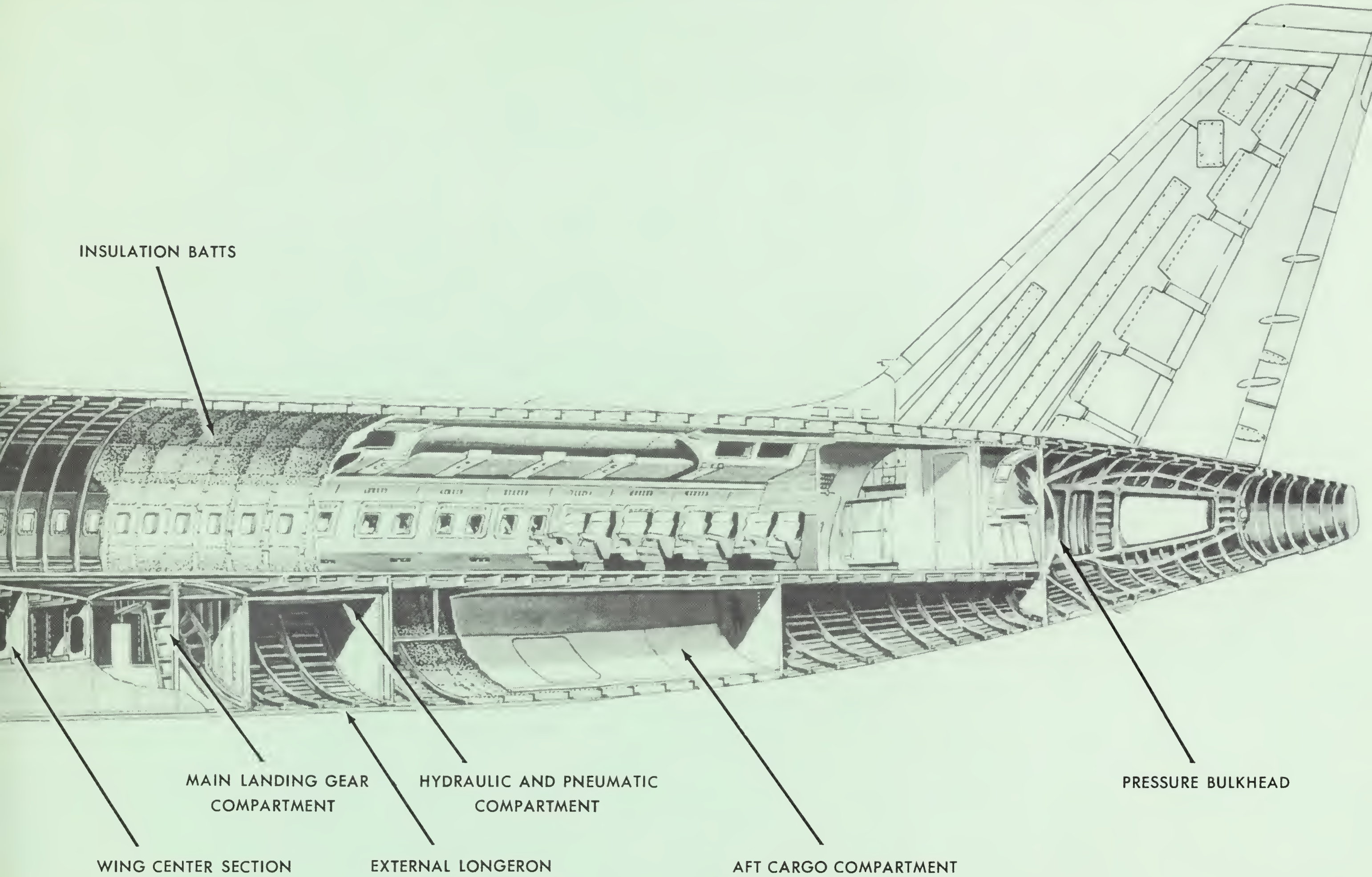


PASSENGER WINDOW DETAIL

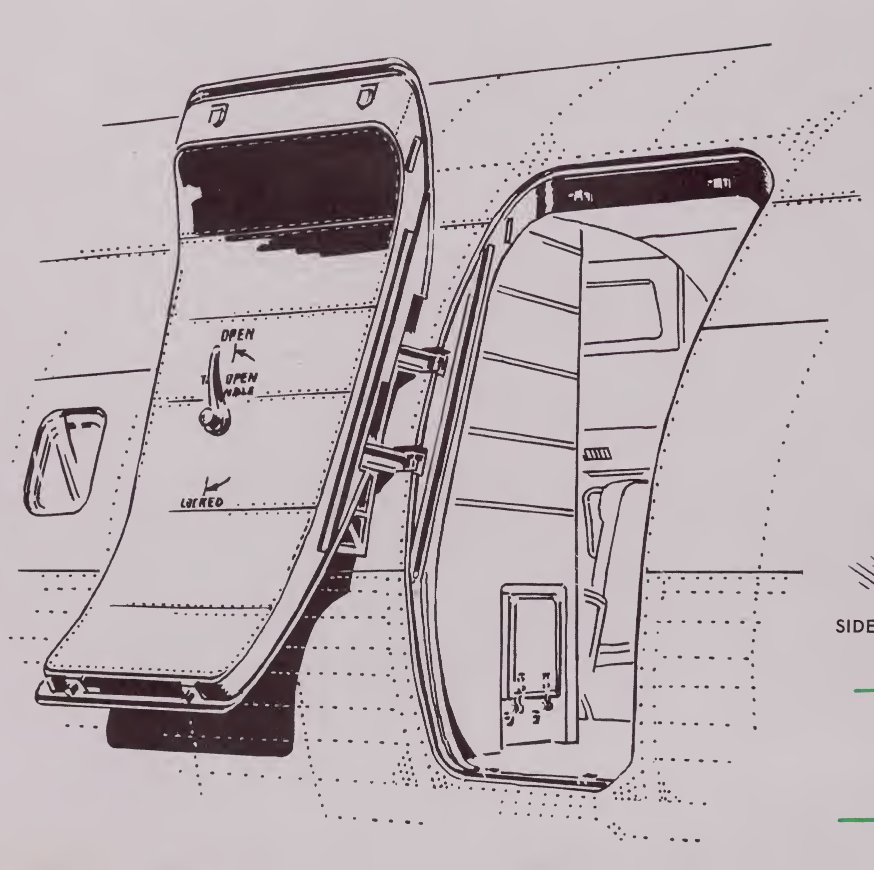
"Fail-Safe" design techniques were applied to all features of construction throughout the Convair 880 fuselage to achieve positive structural integrity. From acoustic attenuation to bird-proofing, and from wind tunnel testing to water tank immersion cycling, all major fuselage components have undergone rigorous testing to ensure an operationally sound airplane.

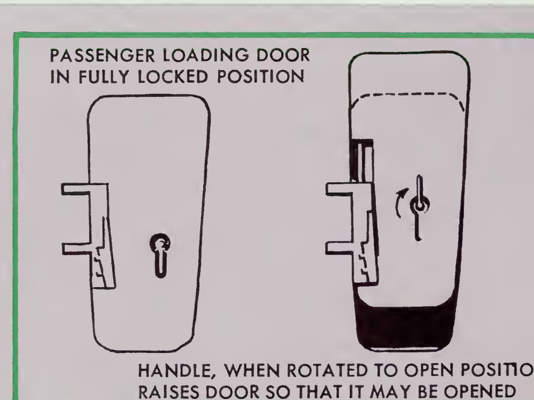
In addition to maximum quiet, vibration-free flight, and the ultimate in seating comfort, the Convair fuselage structure offers extra measures of safety. Due to the extra heavy fuselage skins (.063 to .100), it is expected that skin stresses in the Convair 880 will be low enough to preclude fatigue cracks throughout the life of the airplane.

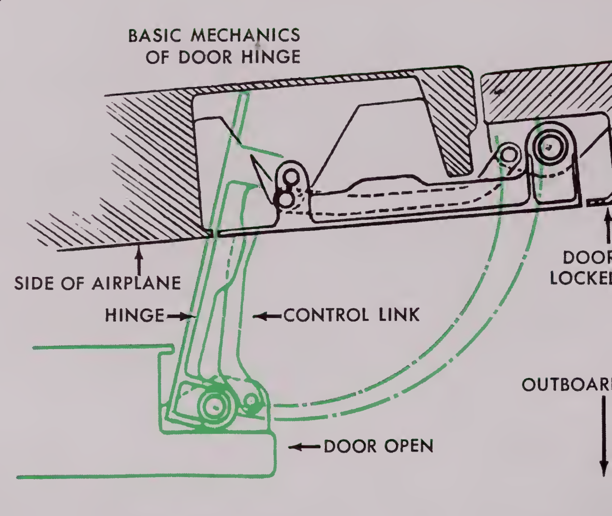
An additional safety feature has been designed into the plug-type loading door, designed exclusively for pressurized high-altitude aircraft. With this design, increasing cabin pressure has a tendency to increase the security and retention of the door under any flight condition.



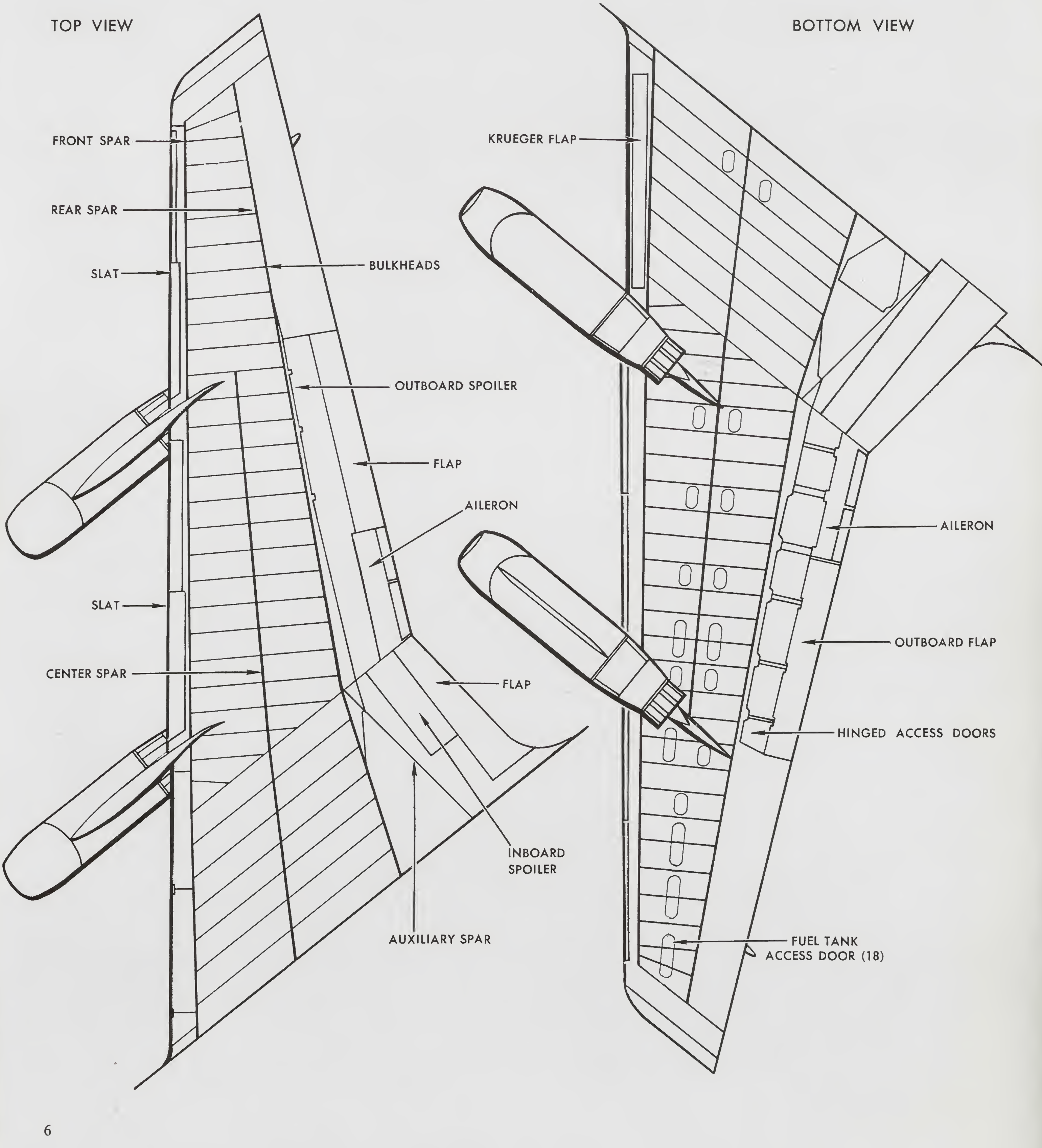
FAIL-SAFE DOOR DESIGN







THE 880M WING STRUCTURE



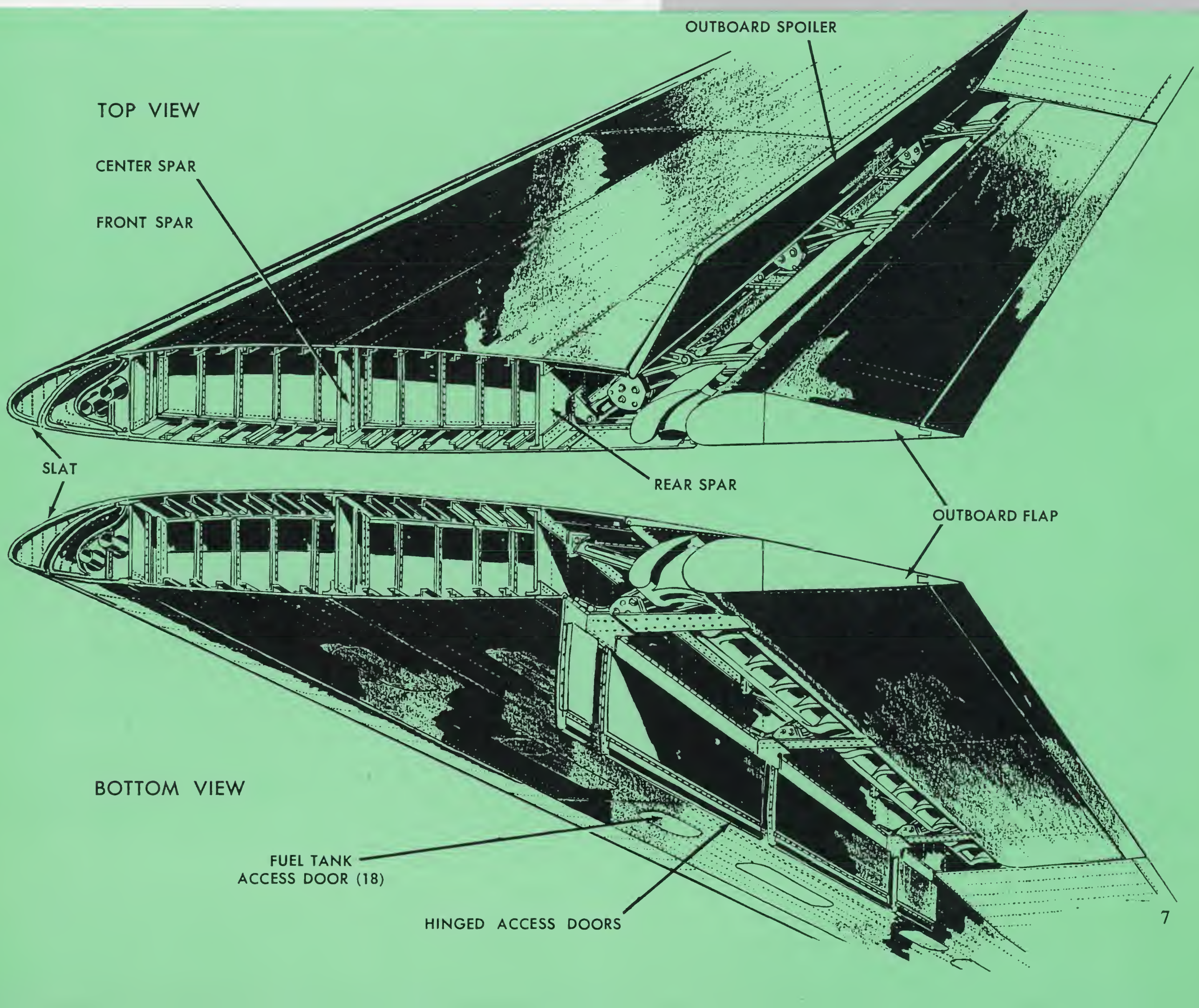
Structural integrity in the wing of the Convair 880 has been achieved through the incorporation of a multitude of "fail-safe" design features. "Fail-Safe" design is accomplished by load and stress distribution throughout the structure so that failure of any given part will not compromise the overall integrity of the wing.

Wing design is of the front, center, and rear spar type with web stiffeners and truss-type bulkheads forming an integral box-like structure. An auxiliary spar, for support of the main landing gear, is joined to the wing box structure and fuselage to maintain maximum integral load and stress distribution.

Employment of the Scotch-Weld adhesive bonding process in the integral wing fuel tanks culminates more than 23 years of advancement in fuel tank design by Convair. The Scotch-Weld process ensures leakproof construction, and contributes a bonus in structural strength and corrosion resistance.

Use of the Scotch-Weld process on the Convair-built F-102 and F-106 supersonic all-weather Air Force jet interceptors has proved its superiority over other methods now employed in the aircraft industry. Its use on the integral wing fuel tanks of the Convair 880 will assure equal maintenance-free, leak-proof operation under all conditions of jet flight.

UPPER & LOWER WING SURFACES



880 MAINTENANCE

Advanced design concepts have virtually precluded the necessity for maintenance in the structural components of the wing and fuselage in the Convair 880.

The "880" is designed to withstand increased landings, taxiing, and takeoffs during short range operation without imposing disadvantages when operating in medium and long range stages.

A significant feature in the design of the pod-pylon assembly contributes to ease of maintenance in the power plant areas. Ready accessibility is achieved through horizontal-opening, full-length doors, permitting access to the power plant.

Design of the "880" embodies parts interchangeability in many areas where such design is practical to facilitate maintenance and to minimize operator inventories of spare parts. Parts interchangeability is incorporated in components and major assemblies of the left- and right-hand main landing gear of the "880."

Special attention has been given to ease of lubrication. All areas that may be susceptible to the entry of foreign matter have been sealed. Pressure lubrication fittings are provided at all points that are subject to friction and wear through the movement of mechanical parts.

Employment of the Scotch-Weld adhesive bonding process in the production of integral wing fuel tanks for the "880" culminates more than 23 years of advancement in fuel tank design by Convair. The new process not only provides leakproof integral fuel tanks, but contributes a bonus in structural strength as well, since the wing is designed to take "abuses" of medium range operation without the extra strength contributed by Scotch-Weld. Its use in the construction of the integral fuel tanks on the Convair 880 assures maintenance-free, leakproof operation under all conditions of jet flight. In addition, the Scotch-Weld priming process provides corrosion-proof surfaces.

Accessibility has been emphasized in the overall design. The wing, for example, has large removable doors in the lower surface to provide access to fuel system components and to allow inspection of the wing interior. These access doors are of the structural type, and are installed with flush screws and self-sealing, dome-type plate nuts.

A special group within the Engineering Department is assigned exclusively to the monitoring of all design development of the "880" airframe to assure optimum maintainability. Support equipment requirements are also under surveillance of the group. The "880" is designed to utilize tools and replacement components that are available as commercial standard.

In the light of work done to date to assure the maintainability of the "880" design, it is apparent that operators who are experienced in the maintenance of other large aircraft will be able to integrate the Convair 880 into their operations with ease.

THE CONVAIR 990 . . .

The world's fastest passenger transport, the Convair 990 jet airliner is the first transcontinental airliner designed for operation at near sonic speeds.

The Convair 990 will be powered by four General Electric CJ805-23 aft-fan engines. Like the CJ805-3 engine, the -23 was developed from the Air Force J79 turbojet which powers the world's fastest B-58 "Hustler" bomber. The CJ805-23 provides greater thrust and lower cost of operation through utilization of the bypass air and fan principle.

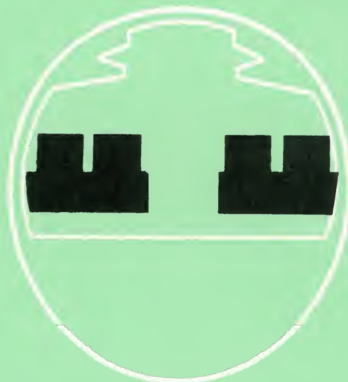
The Convair 990 offers, for the first time in a jet transport, an economical four-across seating arrangement. Luxurious cabin interiors with a wide variety of seating arrangements in both first class and tourist accommodations, and sea-level cabin pressurization at high altitudes assures the maximum in passenger comfort and safety combined with economical operation.

Estimated operating costs, at ranges of 2500 statute miles or more, are lowest of any turbofan airliner of equal capacity flying today. Low turnaround time is another factor that characterizes the Convair 990.

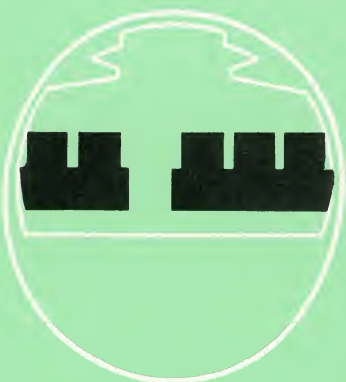
The Convair 990 has been specifically designed for operation from airports presently designed for propeller-driven aircraft.

CONVAIR 990 INTERIORS
(TYPICAL)

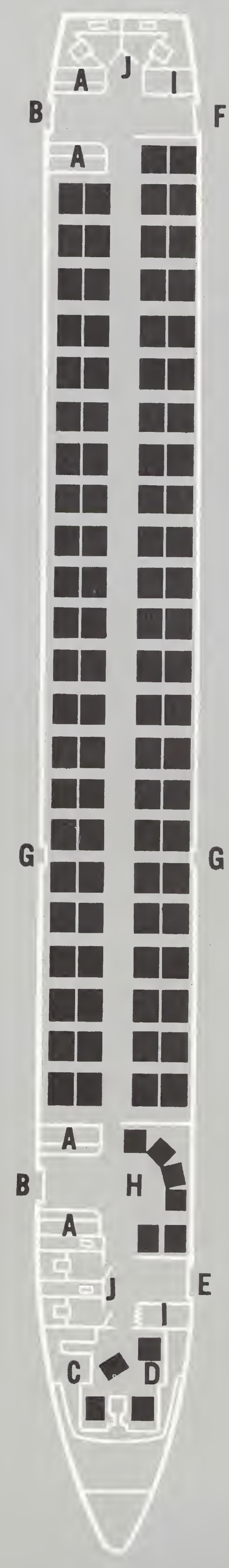
TYPICAL SECTION WITH
STANDARD SEATING



TYPICAL SECTION WITH
COACH SEATING



A BUFFET
B SERVICE DOOR-EMERG. EXIT
C FLIGHT DECK
D OBSERVER'S SEAT
E MAIN ENTRANCE-FWD
F MAIN ENTRANCE-AFT
G EMERG. EXIT EACH SIDE
H LOUNGE
I COAT CLOSET
J LAVATORIES



FIRST-CLASS SEATING ARRANGEMENT — 96 PASSENGERS

ALL-COACH SEATING ARRANGEMENT — 121 PASSENGERS

The Convair 990 provides new standards in comfort, convenience, and safety. The interesting interior design is enhanced by roominess, the cabin being designed with "two-on-the-aisle" seating. In the coach version, three abreast seating is used only on one side of the aisle.

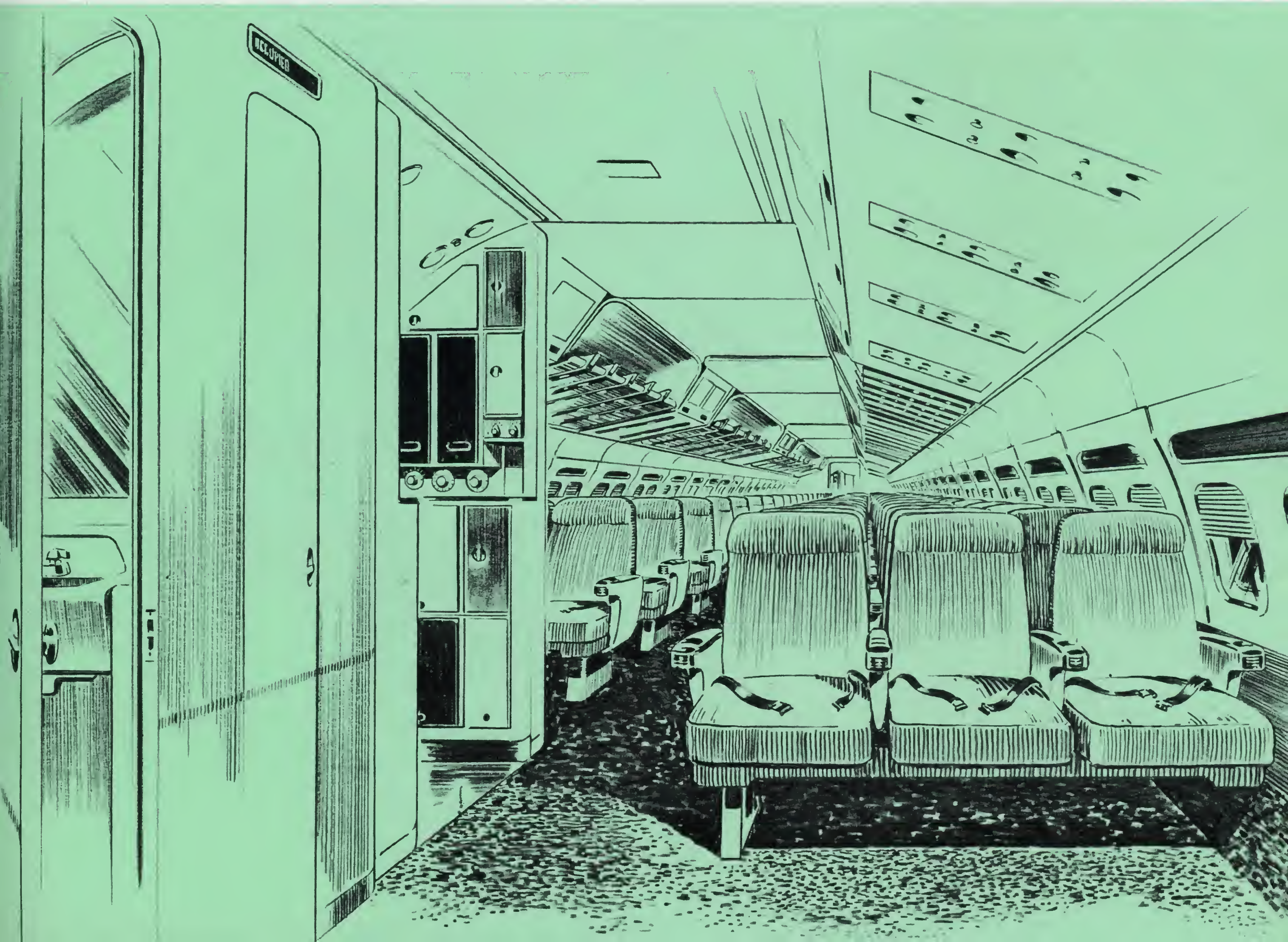
Interior groupings and a feeling of compartmentation are obtained by varying ceiling levels and interior decor without the need for partitions. This interior planning eliminates the tunnel effect sometimes seen in conventional airliners.

In the tourist configuration, passengers will find the same emphasis on spaciousness and comfort. In the five-abreast seating arrangement, arms and shoulder room will be the same as in many present-day deluxe seating arrangements.

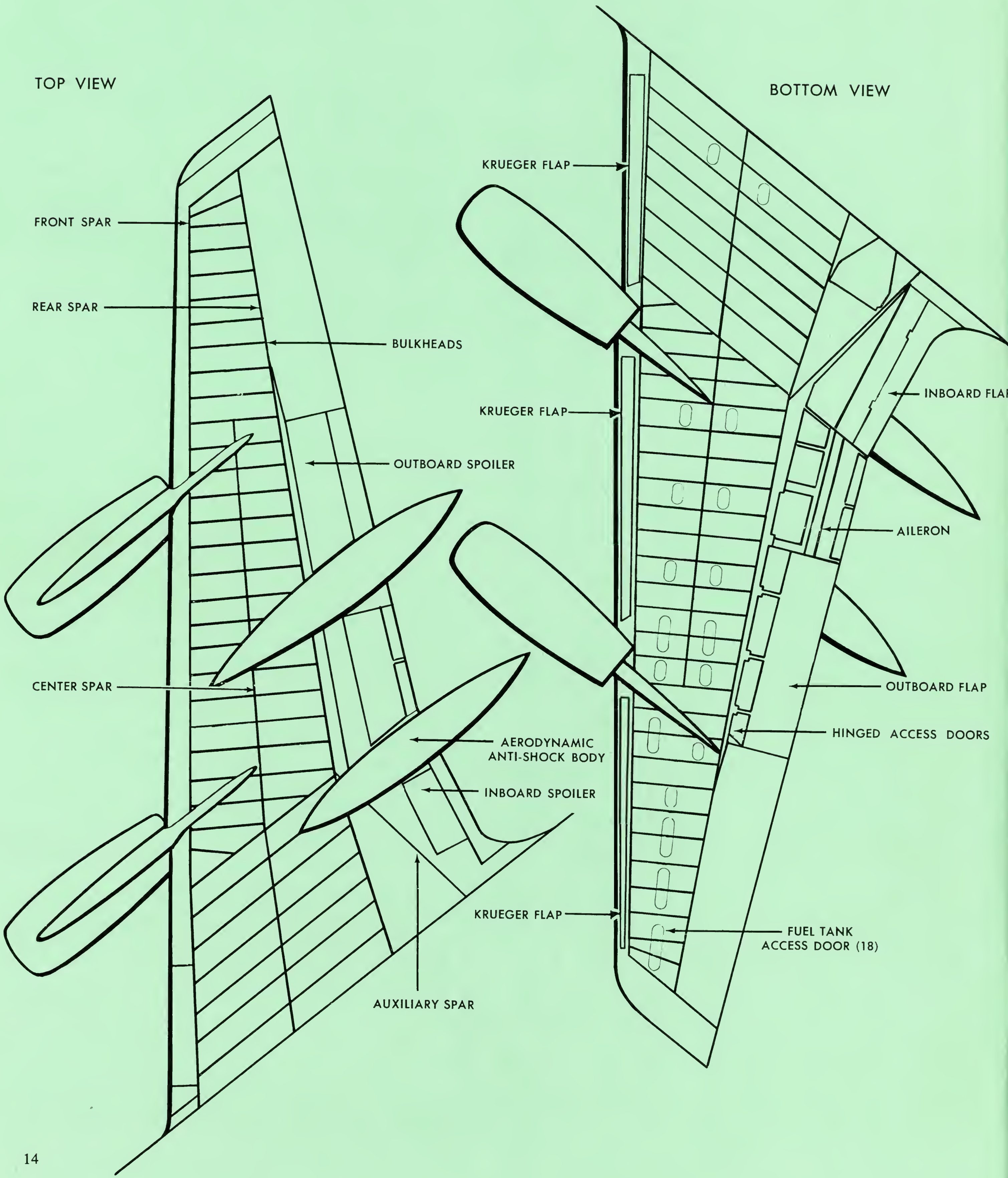
For each passenger, there is a built-in folding tray for food service. The hinged tray is available at a touch of the passenger's fingers. The tray may be used also as a surface for writing. There are four buffets, two forward and two aft. There are two lavatories at each end of the main cabin. A lounge in the forward section provides deluxe seating for six in formal groupings.

The cabin furnishings and interiors are designed with fine textured surfaces for ease of cleaning and maintenance. Fluorescent lighting in ceiling coves provides indirect lighting. Additional indirect lighting at panels above each pair of windows tends to add to the compartmentation effect. Windows, instead of being curtained, are equipped with tinted glass to filter the brighter sunlight encountered at altitudes seven miles above the earth.

COACH CLASS – FIVE-ACROSS SEATING



THE 990 WING STRUCTURE



Wing design of the Convair 990 consists of multiple spanwise spar members, ribs and bulkheads of truss and web-type construction, with plate-stringer type upper and lower surfaces. This box-type structure incorporates the ultimate in "fail-safe" construction by providing equal distribution of flight and landing loads.

Scotch-Weld adhesive bonding is used in the wing and wing fuel tanks to seal and strengthen the structure. This process was pioneered by Convair and has proved itself in military use in F-102 and F-106 interceptors.

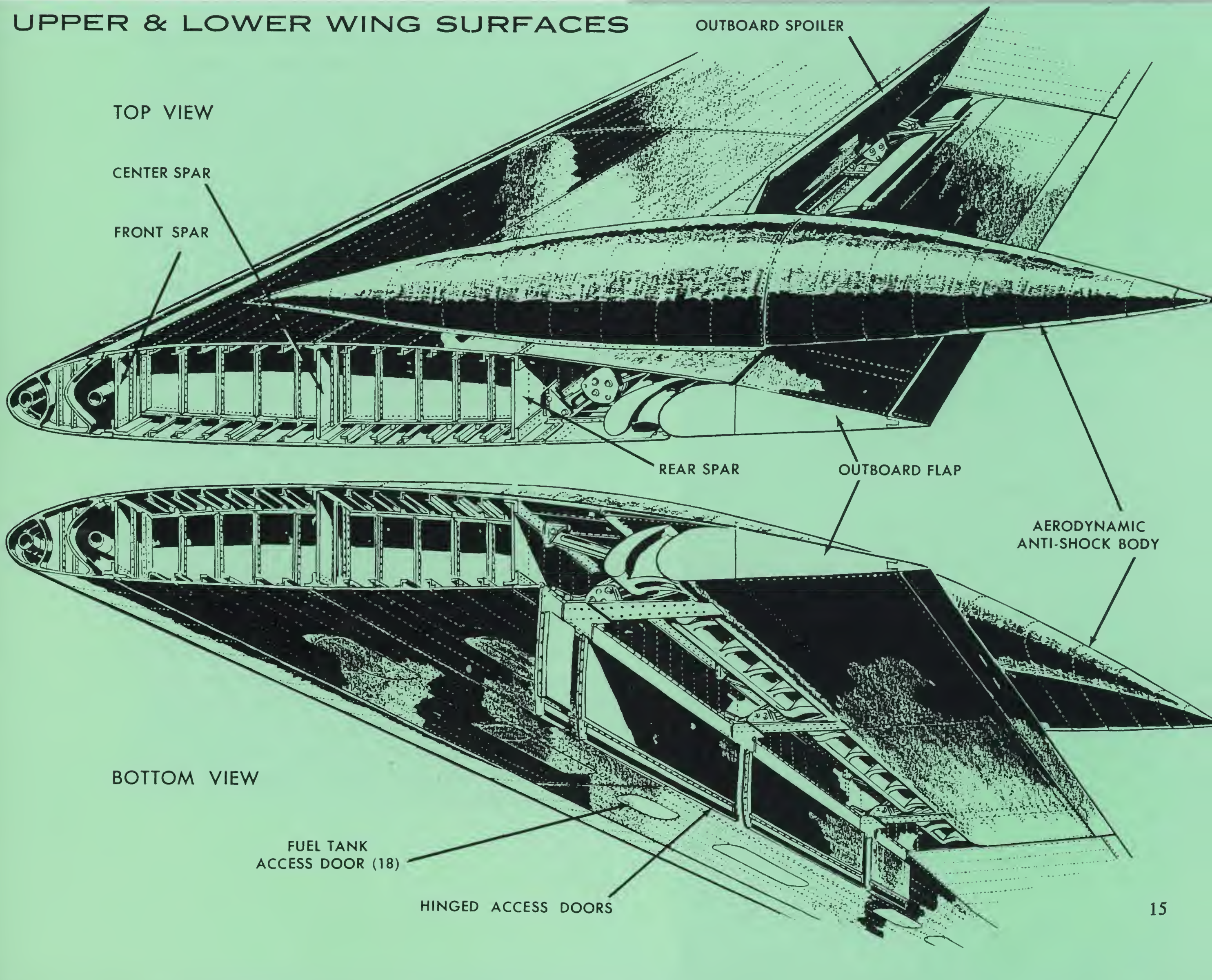
Wings sealed with Scotch-Weld provide strong, leakproof construction. The bonding adds a bonus not only in structural strength but in fatigue and corrosion resistance, and is satisfactory for use with any present-day jet fuel, at temperatures from —65° to 250°F.

Convair-designed anti-shock bodies, mounted on the upper surface of the wing, dissipate shock wave buildup on the wing during operation in the higher Mach ranges. This design and the advanced aerodynamic contouring of the wing, are principal factors in making the "990" the fastest commercial jet transport available.

Fuel capacity for long-range operation is provided in the anti-shock bodies and in tanks in the wing box structure.

Leading edge slats — flap-like extensions of the leading edge that permit high wing angle-of-attack — combine with the flaps to yield high lift at low speeds. Spoilers, flaps, and slats, and advanced wing design, make possible efficient operation at high gross weights from runways now utilized by propeller-driven aircraft.

UPPER & LOWER WING SURFACES



CABIN PRESSURIZATION

The Convair 990 air conditioning and pressurization system is designed to supply all occupied compartments of the airplane with an air flow of 160 pounds of air per minute at sea level, and 120 pounds per minute at 35,000 feet.

The air conditioning system supplies circulating fresh air, heated or cooled, as conditions require. A complete change of air is delivered to the cabin every 2½ minutes and to the flight deck every minute.

The cabin maintains a temperature of 75°F in flight under all ambient temperature conditions and a maximum of 80°F on the ground. At all outside air temperatures . . . whether 100°F or —40°F . . . the air conditioning system keeps passengers comfortable without unpleasant air surges or annoying drafts.

Each passenger has a silent individual cold-air inlet to provide direct airflow, if desired. All air entering the cabin through the outlets below the hatracks is discharged through the side panel floor exit ducts, and then is dumped overboard.

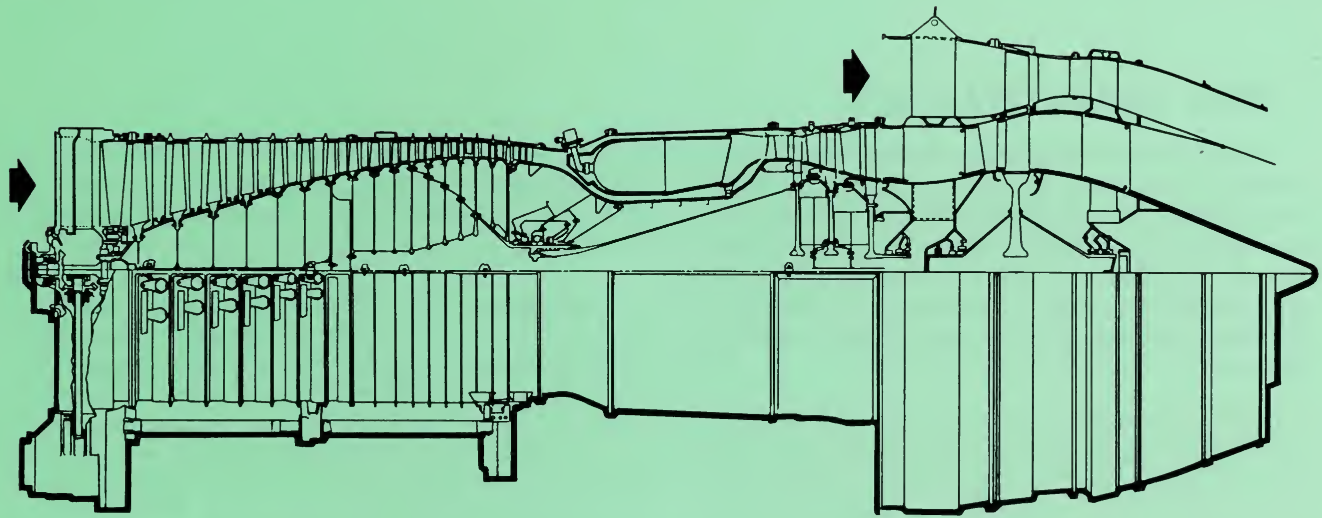
Heating and cooling of baggage compartments and of electrical and electronic equipment is also provided by the air conditioning system.

The Convair 990 can hold a sea level cabin altitude up to an airplane altitude of 21,300 feet, and an 8,000 foot cabin altitude up to an airplane altitude of 41,000 feet. The maximum normal cabin differential operating pressure is 8.2±.10 psi. In event of failure to both cabin pressure regulator sections of the outflow valves, the relief valves will relieve at a differential pressure of 8.5±.10 psi. Signal lights on the flight deck control panel will indicate the respective valve failure, and a warning horn will sound when cabin altitude exceeds 10,000 feet.

Presetting of the rate of change of cabin pressure control permits operating at rapid rates-of-climb and descent with a minimum rate-of-change of cabin altitude. Flow is maintained automatically against all normal loads imposed upon the system by the ever-changing demand for pressurization and ventilation.

The rate of cabin pressure change is selectable from 2000±200 fpm to 65±35 fpm. The nominal calibration is 500 fpm±10 per cent. Deviation from selected cabin pressure rate-of-change during transient conditions will not be greater than ±25 fpm.

The basic air conditioning system is composed of two separate and independent subsystems, pneumatically-driven by bleed air from the CJ805-23 engines. Each subsystem sonsists primarily of a ram air supercharger (bleed air turbine-driven compressor), an air-to-air heat exchanger, and a vapor cycle Freon refrigeration unit.



THE 990 POWER PLANT CJ805-23

The General Electric CJ805-23 aft-fan engine is the newest available modification of the jet engine principle, combining the best elements of jet and propeller operation.

The aft fan, as its name implies, is driven by exhaust gases aft of the compressor turbine at comparatively high speed. The fan blades are turbine buckets at the root half, compressor blades at the tip half. The fan has the effect of driving a greatly increased volume of air aft, at a somewhat slower speed than the jet blast, adding to the engine's overall thrust.

The propulsive efficiency of aircraft power plants is determined by the ratio of gas velocity to aircraft speed, whether the power plants are propeller, jet, or fan types. Ideal obtainable efficiency is reached when jet velocity is 1½ to 2 times aircraft velocity, which is approximated by the fan engine design.

The CJ805-23 is designed for ideal efficiency in the Mach .8 to Mach .9 speed range. At this cruise range, the jet-to-aircraft velocity ratio is approximately 1:7.

The CJ805-23 has the highest bypass ratio of any turbine fan currently being offered — 1.56:1. This bypass ratio was selected because it gives optimum specific fuel consumption for the design cruise range. In addition, the high bypass ratio provides a substantial improvement in takeoff thrust without the need for increased turbine temperature over the straight turbojet.

The aft fan of the CJ805-23 is free-floating. It is supported fore and aft by its own bearings, and is not connected to the basic compressor/turbine rotor. It is a single-stage fan with integral turbine and compressor sections.

The aft-fan front and rear frames have eight all-steel struts. The outer struts are anti-iced at the leading and trailing edges.

Possibly the most important single advantage of the CJ805-23 aft-fan engine is its low cost of operation. The CJ805-23 engine uses the same gas generator as does the CJ805-3B—the simplest offered today. The -23 engine provides the same ease of inspection, assembly and disassembly, and the same economy of maintenance and overhaul as does the CJ805-3B.

A thrust reverser, producing up to 50% engine thrust in the reverse direction, is a part of the engine assembly.

The takeoff and climb thrust of the CJ805-23 has very important advantages: it gets aircraft to altitude faster, minimizing the noise problem in communities surrounding airports; and it permits takeoff from shorter runways at high gross weight.

990 MAINTENANCE

Design of the Convair 990 jet airliner was planned to effect the maximum utilization of current facilities and ground handling equipment and a minimum of maintenance. New equipment items needed for support of the airplane are electrical power and pneumatic compressor units at route stations. All other servicing functions can be accomplished by existing equipment, with little or no modification.

The Convair 990 may be towed forward or backward by any tug capable of towing other large aircraft. A power source at the tug is required to provide light and communication power, and for operation of the aircraft emergency hydraulic pump to assure adequate brake pressure. The nose wheel steering disconnect permits a 360-degree swivel of the nose wheel.

In taxi operations, the "990" compares advantageously with large propeller-driven transports. With a wheel tread of 20 feet, 1 inch, and a wheel base of 57 feet, 1¼ inches, the "990" has a turning radius of 65 feet with a nose wheel steering angle of 63 degrees. No expansion of existing parking, loading, and taxi-way areas is necessary.

Built-in structural integrity of the "990" has been carefully calculated to minimize maintenance, and to provide an ease of maintenance unparalleled in the jet transport field. This has been achieved through the utilization of bonus features which have become an integral design characteristic throughout the structure of the "990."

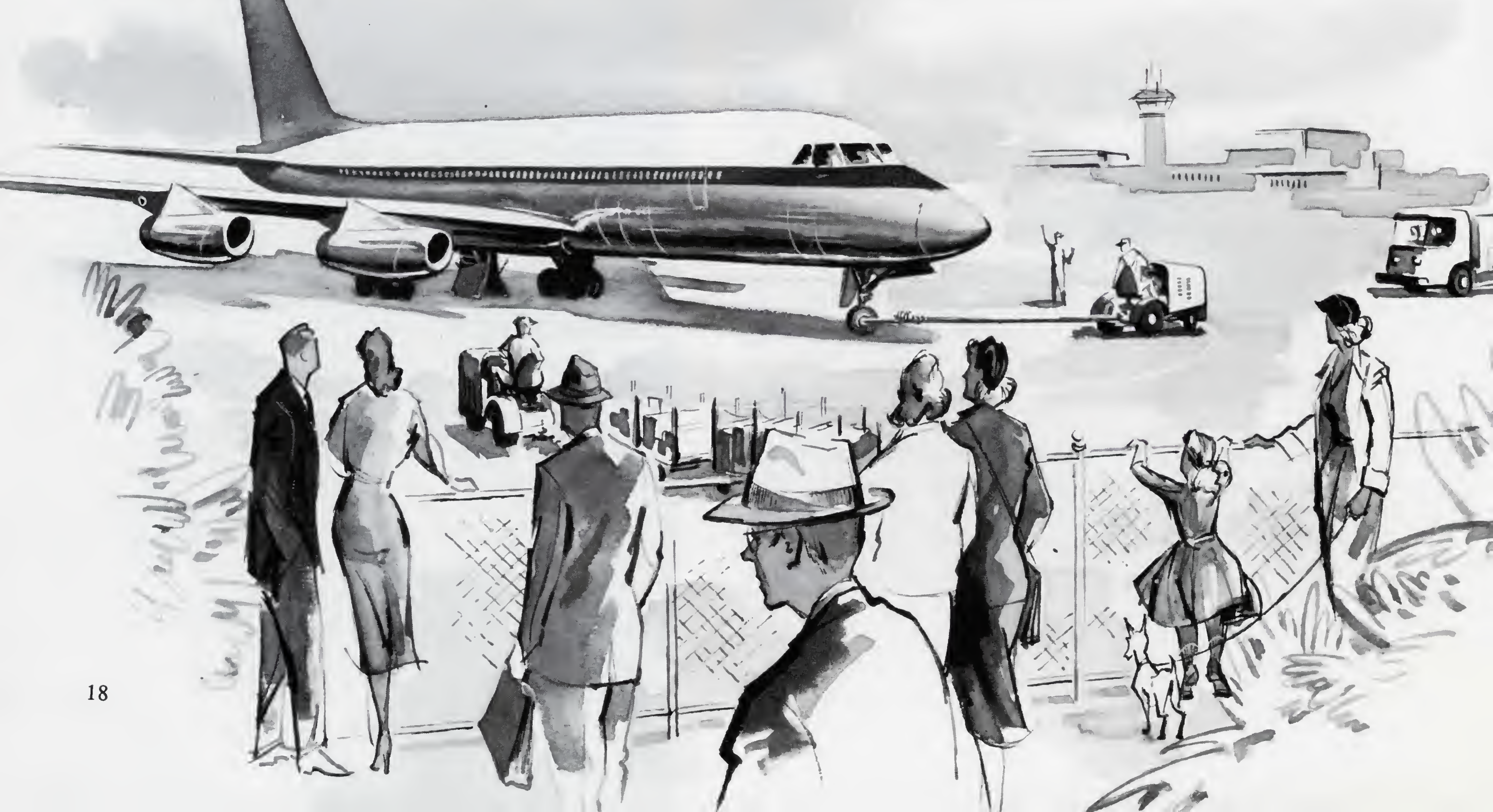
Convair has developed an integral method of fuel tank construction which eliminates fuel tank leaks. Sealing of the fuel tanks by the Scotch-Weld method not only eliminates leaks, but eliminates corrosion, and provides a bonus in structural strength within the wing.

The selection of a General Electric "package" electrical system, tailored to the requirements of the "990" jet transport, is expected to simplify maintenance, thus minimizing service man-hours and stopover time. By obtaining the complete electrical system from one vendor, a ready supply of such spare parts as may be needed will be assured, and problems involving the system can be given concentrated attention.

The CJ805-23 power plant is characterized by unusual simplicity of design. The turbine, combustion, and compressor sections are structurally surrounded by removable casings of horizontally split-type construction, which facilitate rapid access when performing internal inspection and adjustments. Removal and replacement of the engine can be accomplished in approximately 30 minutes.

Turnaround servicing ordinarily will not require raising the side panels of the pod assembly. Doors are provided in the cowling alongside the pylon for access to the oil tank fill ports for checking oil level and filling. When the panels are raised, all lines and accessories are immediately accessible, not only for inspection but for replacement of accessories and components in line maintenance.

Service doors are so located that servicing of the aircraft does not interfere with cargo and passenger loading.



Convair 990 Aerodynamic "Speed Capsules"

Soon to be streaking across the skies faster than other jet airliners will be the Convair 990. Nudging sonic speeds at Mach .91 — within 9 percent of the speed of sound — the "990" will span the North American continent three quarters of an hour faster than competitive aircraft.

Employing the advanced engineering concept of special aerodynamic anti-shock bodies on the upper surface of its wing, this sleek airliner will leave most of the drag-inducing shock waves behind as it is thrust through the edge of the stratosphere by its powerful turbofan engines. Inside the spacious cabin, its passengers will enjoy the most luxurious flight they have ever experienced, confident in the knowledge that they are flying in the safest, most finely engineered airliner of the day.

After the design of its predecessor, the Convair 880, was frozen, research continued toward the development of a new version with reductions in transonic drag and increases in high lift capabilities. The ensuing effort culminated in the design of the Convair 990.

Convair initiated the program by taking the basic 880 configuration, extending the fuselage 11 ft, 3 inches, changing the power plants to the powerful, efficient GE CJ805-23 aft fan engines, and adding 25 inches to the wing trailing edge. Because the new airplane was to cruise at high subsonic speeds (just under the speed of sound), a great deal of effort was devoted to finding a means of delaying the formation of shock waves of air which tended to "cling" to the upper surface of the wing, creating drag. Such shock waves form at high subsonic speeds if the air, flowing over the cambered upper surface of the wing, accelerates to supersonic speed.

"880" AND "990" CONFIGURATION

The breakthrough came by the use of anti-shock bodies, the now familiar "speed capsules," positioned over the wing where the shock strength is the greatest. These streamlined bodies reduce shock waves on the wing upper surface, by reducing the local velocity of the air flow and delaying its transition to supersonic speed.

Elimination of high-speed drag effect with anti-shock bodies was studied in extensive wind tunnel tests carried out in 1958 at the Southern California Cooperative Wind Tunnel at Pasadena. By the use of a fluorescent oil-film, the boundary-layer flow over a scale model "990" wing was observed in the wind tunnel. It was learned that the use of anti-shock bodies increased the average "990" cruise speed (weight, 180,000 pounds, altitude, 30,000 feet) from Mach .88 to Mach .90. This is an increase in speed to approximately 635 miles per hour at an altitude of 25,000 feet. The accompanying photographs, taken in the wind tunnel at the time of testing, dramatically show the difference in air flow over a "990" wing with and without the anti-shock bodies.

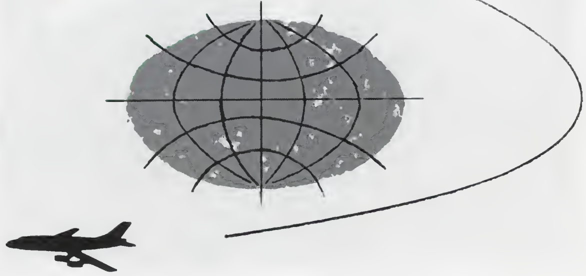
Additional studies of anti-shock body lengths, size, and area distribution were made to obtain minimum drag. Tests conducted at the Langley Wind Tunnel by the National Advisory Committee for Aeronautics were studied, and resultant findings were applied to Convair's own research.

At the Langley 8-foot transonic wind tunnel, an experimental study was made of the effects on aerodynamic characteristics of special bodies on the upper surface of a swept-back wing at subsonic Mach numbers. The Mach numbers ranged between .60 and 1.00. The study revealed that the presence of the bodies caused significant reductions of the shock-induced boundary-layer separation at lifting conditions and, therefore, marked reductions of the drag at subsonic Mach numbers. Tests were also conducted using various shapes of fuselage anti-shock bodies, but results showed that the greatest overall benefits were derived from anti-shock bodies on the wing.

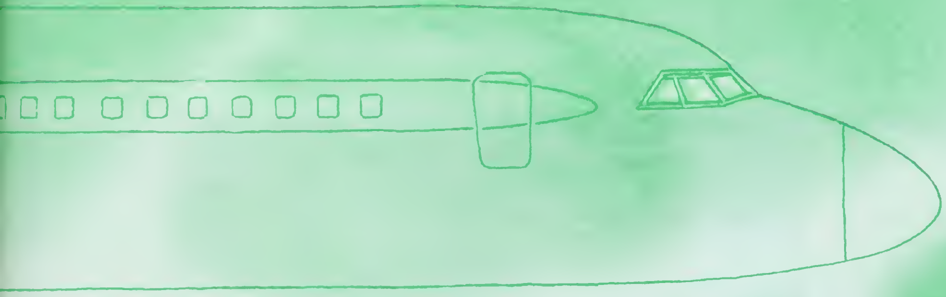
At subsonic speeds, separated flow behind the wing shock wave accounted for the major portion of the compressibility drag. Improvements in transonic characteristics could be accomplished only by elimination, or reduction, of this shock-induced boundary layer separation. Two possible methods of accomplishing this were to either energize the boundary layer or to weaken the shock wave. Vortex generators (low span-wise fences) were tested, but they failed to minimize the drag at Mach .91 where the shock wave was strong enough to separate the energized boundary layer. It was decided that the only way to achieve the required drag reduction at or above Mach .91 was to reduce the shock strength. Hence the anti-shock bodies which, when positioned over the "990" wing where the shock strength was the greatest, accomplished this end.

Wind tunnel photo clearly defines shock waves on a wing without aerodynamic speed capsules.

With aerodynamic speed capsules on wing, shock waves do not form, air flows smoothly over wing.



A most welcome "bonus" derived from the 990 "speed capsules" (anti-shock bodies) is the extended range made possible by utilizing the forward portion of each capsule as a fuel container. The extra 1136 gallons of fuel so carried brings the total fuel capacity to 15,108 gallons and puts the Convair 990 in the intercontinental class. The Convair 990 will be able to race the sun across the land, and win.



STRUCTURAL INTEGRITY of the CONVAIR "880" FUSELAGE

The term "fail-safe" has been synonymous with Convair aircraft since the first 240 transport came off the production line in 1947.

Convair has long been aware of the importance of repeated load testing as an essential part of developing the fatigue-resistance of an aircraft structure, and the tests conducted during the past several years on 240 and 340 aircraft have been directed toward that end. Only by extensive fatigue tests can the designer be sure that the preliminary safety measures he has incorporated will actually be effective.

Developments in the "880" structural test program to date include preliminary testing of cabin windows and windshields, and structural and crack propagation tests of the fuselage structure. High- and low-speed wind tunnel testing of five scale models was also conducted to determine air loads and their distribution.

Although subassembly tests are the principal tool of fatigue investigations, a structure without any fatigue critical areas can be guaranteed only by fatigue tests of the structure as a whole. Such tests provide a means of more accurately reproducing all the stresses that act simultaneously within the airframe.

In recognition of this fact, a comprehensive "880" fuselage test will be conducted in a water tank with a complete fuselage and stub wing assembly. To this specimen will be applied many cycles of combined pressurization and flight loads, with landing loads interspersed between programs of flight cycles.

It is expected that skin stresses in the fuselage of the Convair 880 will be low enough to preclude fatigue cracks throughout the life of the airplane. Nevertheless, Convair, being aware that fatigue is not the only phenomenon that may start a skin rupture, has undertaken an extensive test program to demonstrate that such ruptures, if they should occur, will not result in a major failure under normal operating conditions prior to their detection by inspection.

A series of fail-safe tests were conducted in which various members were cut, and loads applied to demonstrate that the "880" structure or section considered retained its integrity. Emphasis was placed on very low rates of crack growth. In no case did explosive failure occur in any of the fuselage frames and panels tested.

The most drastic test involved dropping a steel javelin through the fuselage skin of a test section under pressure. Although a substantial cut was made, there was no evidence of additional structural failure.

A test section of fuselage skin under pressure is subjected to the javelin test.

Research in sound suppression is currently centered in the new Convair Acoustics Laboratory, where Convair engineers are developing the quietest passenger cabin possible for the "880." The tests are being conducted to determine the selection of proper skin panel damping materials and methods, and to measure the differences in sound decay with and without damping materials.

The philosophy of employing acoustic mass attenuation by applying thick skins (.063 inch to .100 inch) to the fuselage has been utilized. In one of the laboratory units at the Convair acoustical facility, a test panel is placed in an opening provided in the partition between a reverberation chamber and an echo-free chamber.

Electronic noise generators, amplifiers and loudspeakers project the required volume and frequency of sound into the reverberation room. The sample under test reflects, transmits, or absorbs this sound in varying degrees. The amount of noise that escapes through the sample into the anechoic chamber is measured.

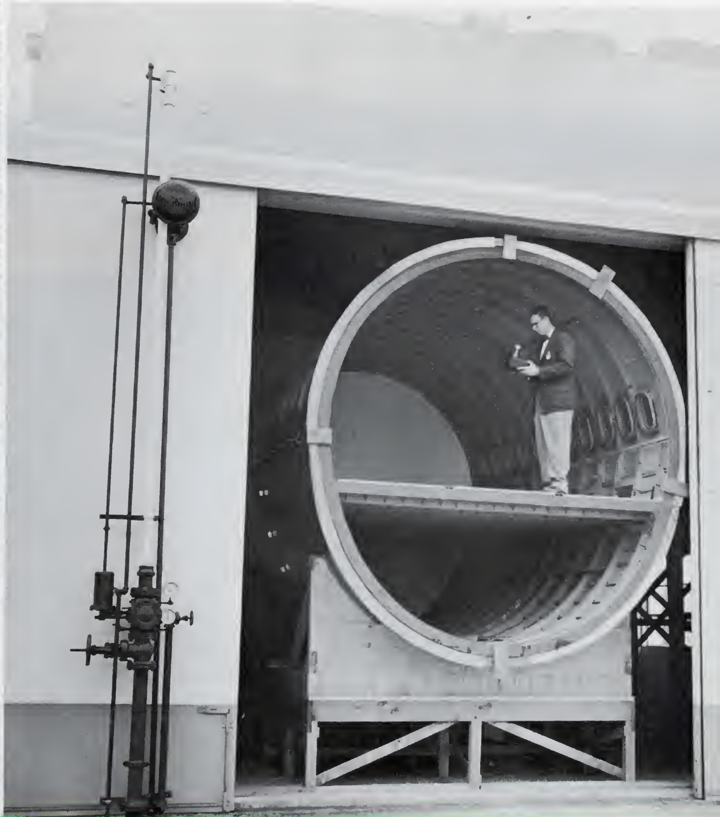
All kinds of noise — the complete audible spectrum from 15 to 15,000 cycles per second, or any desired single frequency or band of frequencies — are projected into the reverberation room through loudspeakers. Its modular concrete walls break up standing sound waves and thus create a uniform audio field in which specimens can be tested. Almost all the sound projected into the room is reflected by walls, ceiling and floor.

In the anechoic chamber, on the other side of the test panel, reflected sound is reduced to an absolute minimum. Sound radiates in all directions from a source, and the glass fiber wedges, which form the interior surfaces of the room, trap and absorb any sound transmitted through the test specimen into the chamber. The fiber itself attenuates high frequencies, and the wedge shapes, into which it is formed, absorb the low frequencies. A removable floor grating allows engineers to walk into the chamber to set up tests and instrumentation.

Research in sound suppression and noise measurement takes place at the Convair Acoustics Laboratory.

A specimen section of the "880" cabin, later to be subjected to strenuous fail-safe tests, nears completion.

Noise escaping through a fuselage test panel is measured in the Acoustic Laboratory's anechoic chamber.



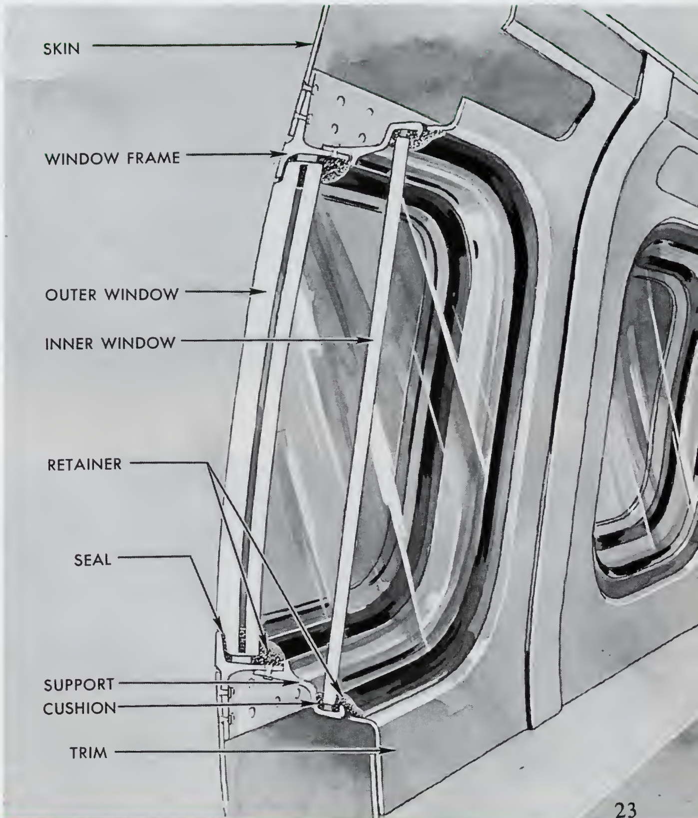
A full-scale, 19-foot specimen of the cabin constant section awaits acoustical testing in the reverberation chamber.

A window for an "880" jet transport can be mounted in the test opening and subjected to the "white" noise (all audible frequencies) produced by the CJ-805 turbojet engines, electronically simulated. Instruments in the anechoic chamber then can measure accurately the amount of jet engine noise each window would admit to the "880" passenger cabin.

Two panes of stretched Plexiglass 55, separated but formed into a single outer unit, plus an inner window pane mounted in rubber, make up the window itself. Structural load can be absorbed by either of the two outer panels.

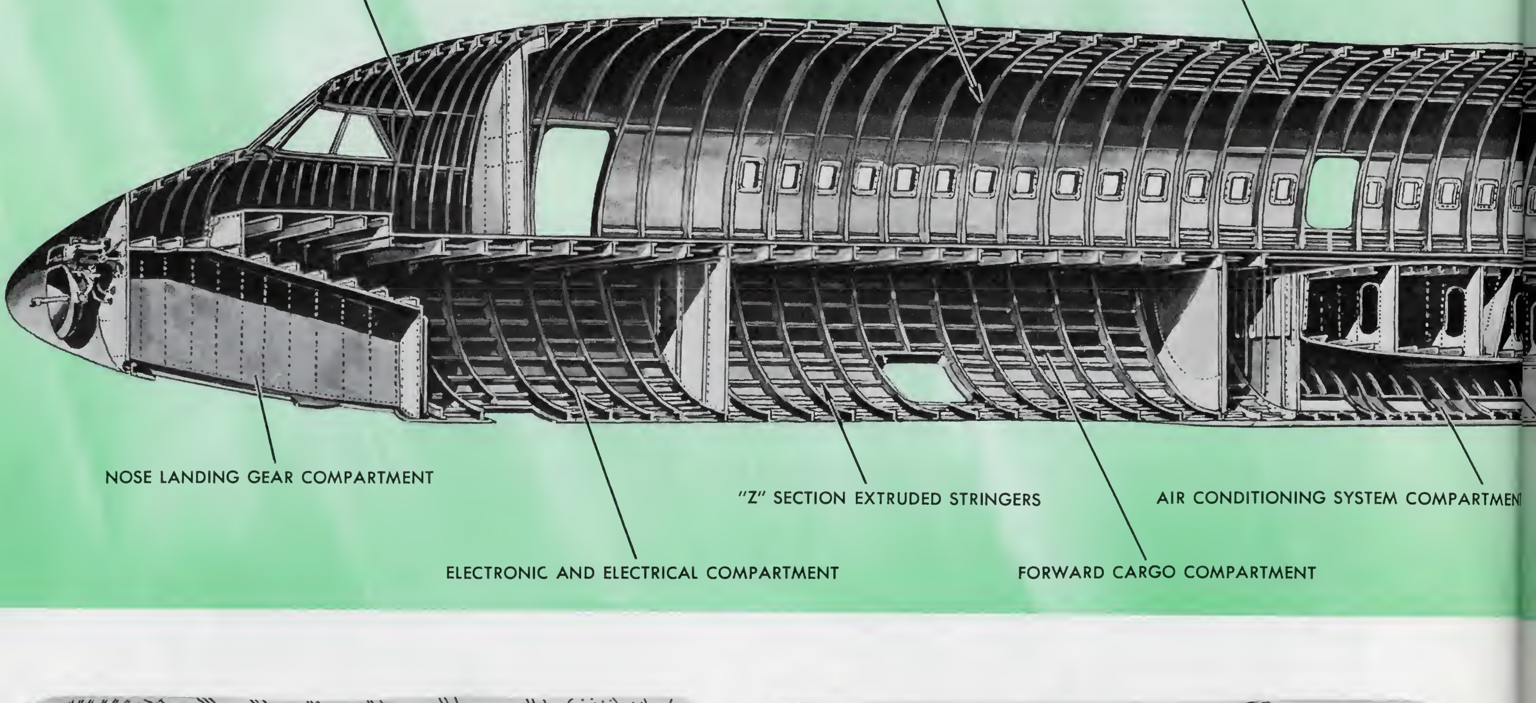
Other preliminary testing of cabin windows has been completed. Window installations were subjected to structural tests involving forces such as shear, torque, tension, and compression.

Placement of windows in the "880" allows two windows per seat row on each side, or four for each cabin bay. Windows are approximately 9 x 12½ inches in size, and the frames are a single-piece aluminum alloy forging. Support for the frames is supplied by the heavy skin, which eliminates the need for longerons around windows.

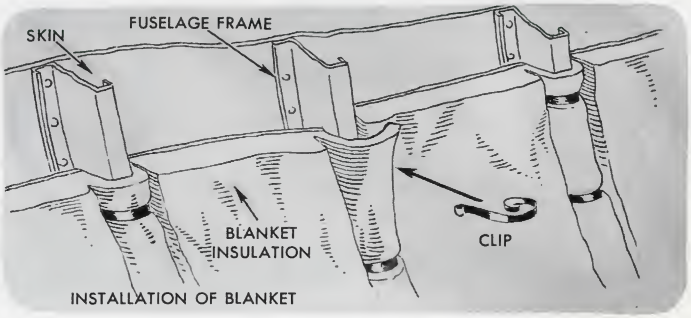


Typical Cabin Window Installation

SECTIONAL VIEW SHOWING STRUCTURAL DETAIL of th



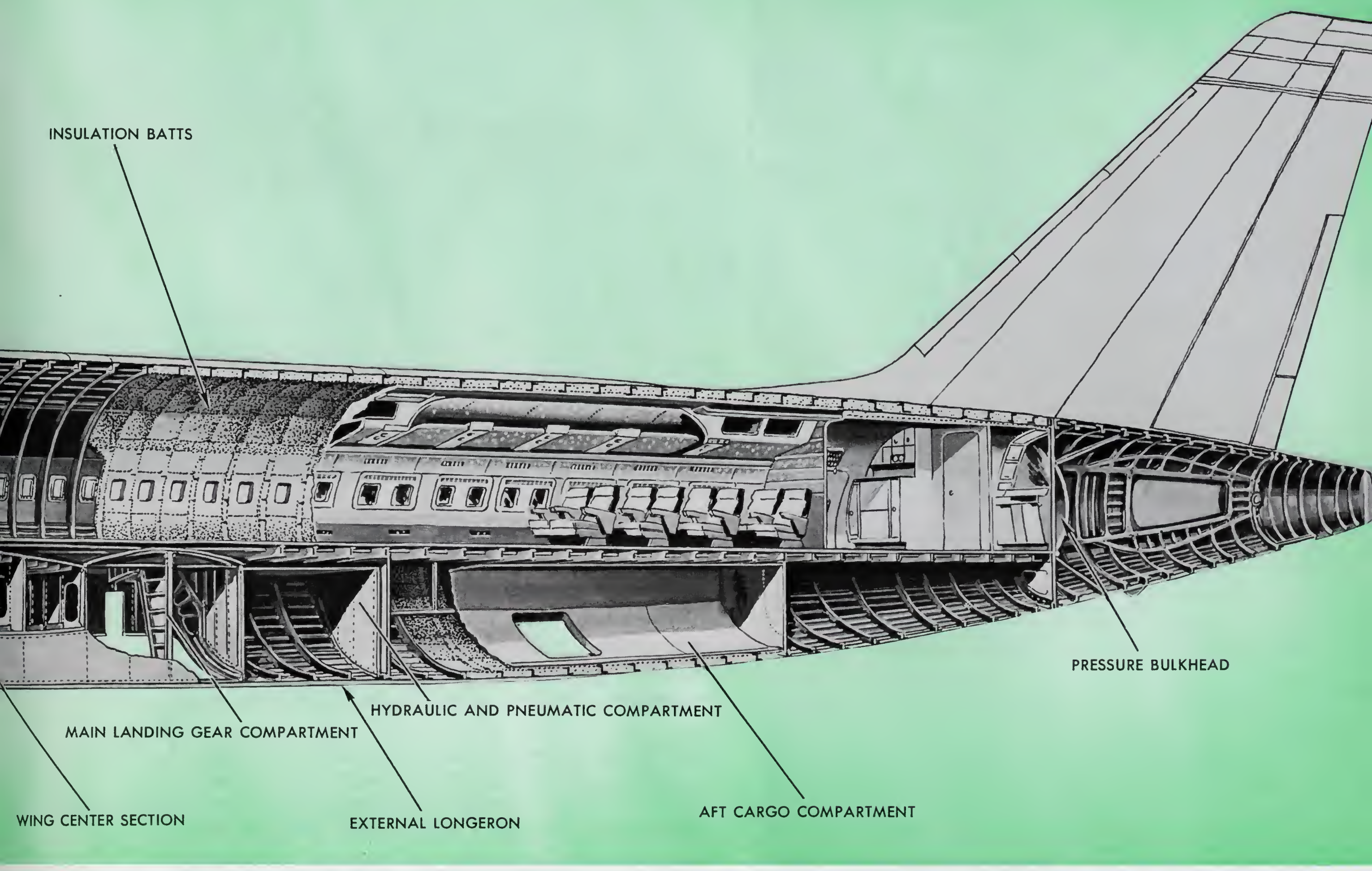
HEAVY SKIN ELIMINATES MANY STRINGERS, SAVES WEIGHT, ADDS STRENGTH

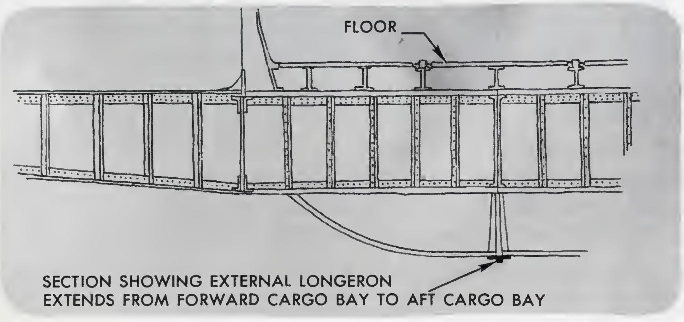


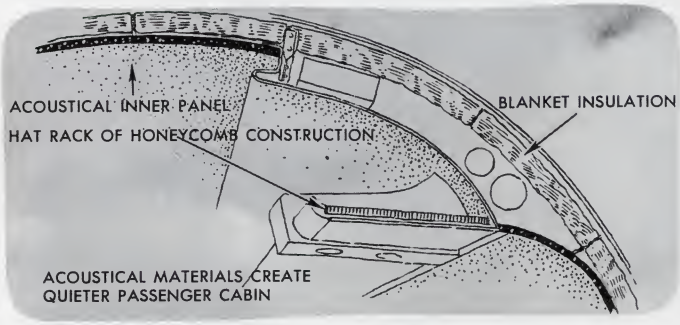
INSTALLATION OF BLANKET

CONVAIR "880" FUSELAGE

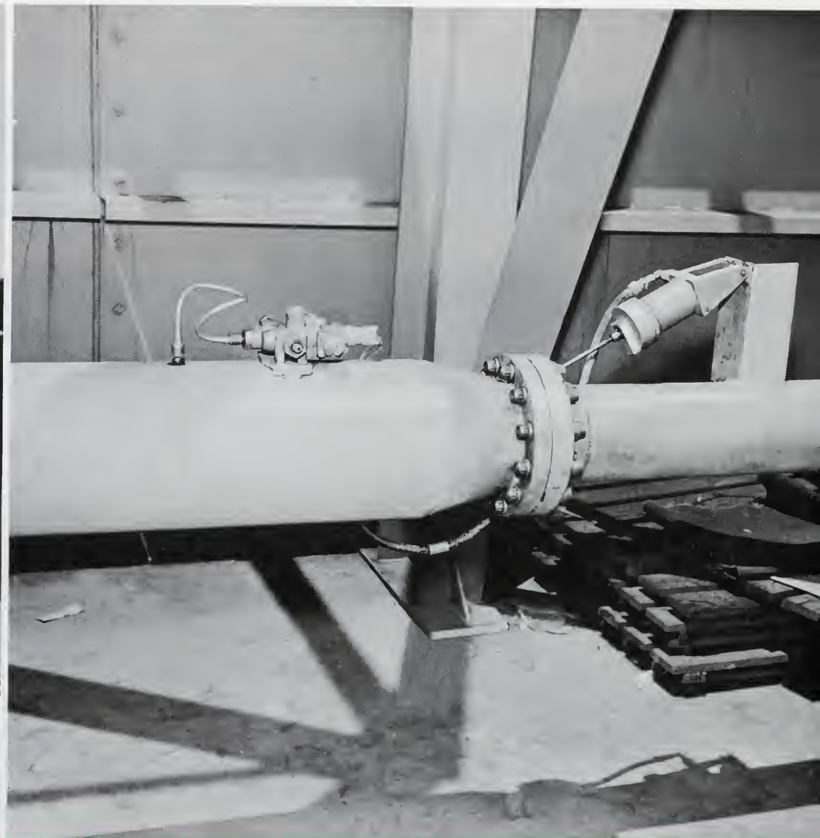
The structural soundness of the Convair 880 fuselage is exposed in detail in this over-all nose-to-tail sectional drawing.







Nitrogen under pressure is used as a propellant in windshield bird-proofing tests employing an air gun.



A solenoid valve is triggered to release the chamber pressure which accelerates the chicken through the gun barrel.

The net result is that heavier skin in the "880" fuselage will reduce the amount of acoustical tape, glass fiber, and other soundproofing agents required, and will insure added protection against explosive decompression with no significant weight penalty.

Preliminary bird-proofing tests on the main windshield have also been completed. Purpose of these tests was to satisfy the bird-proof strength requirements of the windshields, which will be incorporated in the "880," and to prove the structural integrity of the windshield panels. Actual tests involved use of an air gun installed at the Convair Structures Ramp Facility in San Diego.

Windshield bird-proofing tests are conducted at the Convair Structures Ramp Facility.

A chicken weighing approximately four pounds was chloroformed just prior to each test, and encased in a transparent polyvinyl alcohol bag. The bag containing the chicken was inserted in the barrel of the gun at the breech. Mylar diaphragms of the proper thickness were set in a recess between the chicken and a pressure chamber, to which the barrel was bolted.

Nitrogen under pressure was bled into the pressure chamber until the desired pressure was reached. A solenoid valve was triggered, allowing this pressure chamber to activate a knife-ended plunger which ruptured the diaphragm and released the chamber pressure to accelerate the chicken down the barrel.

Windshields were mounted in a frame which was located transversely to the desired position in front of the gun. The speed of the chicken was computed by analysis of high-speed films taken at the end of the barrel while the chicken was traveling between gun and windshield. The distance it traveled per frame was read from a calibrated board in the background, and the speed of the film was determined by timing marks made by a pulse generator. The gun was capable of firing the bird at velocities far above the cruise speed of the new airplane.

Chicken's speed as it contacts the frame-mounted test windshields is computed by analysis of high-speed films.

Advanced bird-proofing tests on center and main windshields have just been completed, with final selection of the "880" windshield to be made from panels tested.

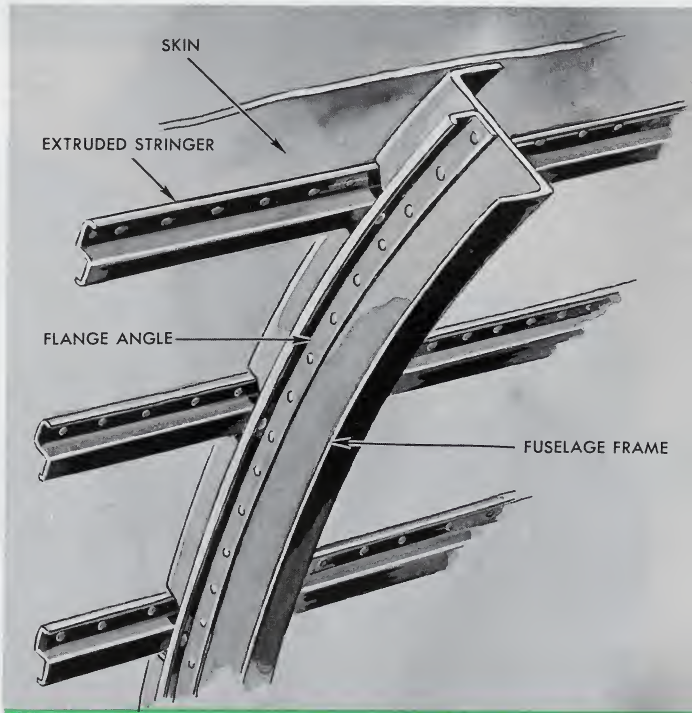
These various tests have given Convair design engineers the knowledge to design a passenger cabin for the high-speed, high-altitude Convair 880 — a passenger cabin that has insured protection against structural fatigue which might otherwise cause explosive decompression.

Aluminum alloy 2024, noted for its superior resistance to crack propagation, is used throughout for the fuselage skin. Its gauge ranges from .063 to .100. The minimum skin gauge in the pressure cabin is .063, and the maximum gross hoop tension stress is 8500 psi at 8.2 psi cabin pressure. Above the cabin floor line where the windows and most openings are located, the heavier gauges will be used.

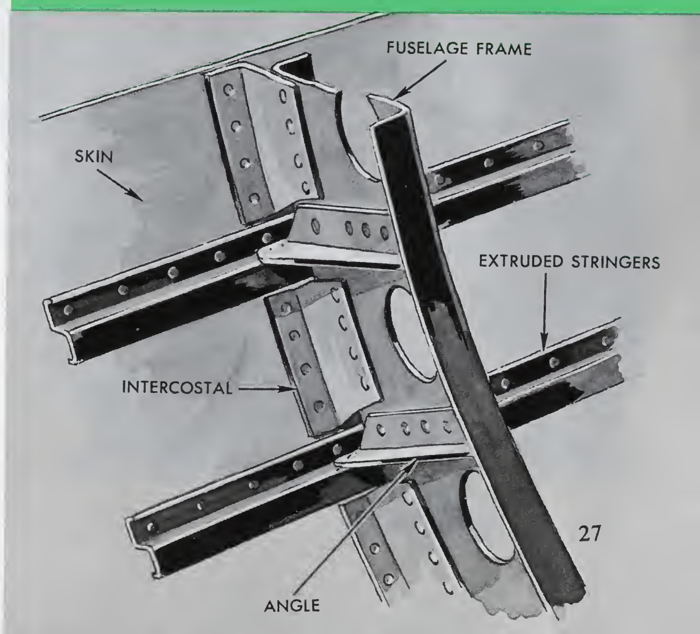
Use of the heavier skin also eliminates the need for stringers over a considerable area. This will result in lower pressurization-induced stresses, and in weight reduction.

Typical stringers are .050 gauge, and generally are ⅞-inch deep, extruded 7075 aluminum alloy Z-sections. Stringers numbered 9 to 17, approximately centered on the floor line, are 2024, and spacing is approximately six inches. Below this region, spacing is nine inches, except in areas fore and aft of the wing. Above the area of greatest radius, stringers are eliminated up to a point varying from approximately 15 to 40 inches from the top center line. Width of stringer installation in this top area is greatest over the wing.

Fuselage frames in the "880" are stretch-formed 7075 Z-sections, and a typical frame is 3⅛ inches deep and of .050 gauge.



Typical Fuselage Frame and Stringer Intersections



The aft pressure bulkhead is located forward of the horizontal stabilizer so as to eliminate sealing problems, because this surface is adjustable.

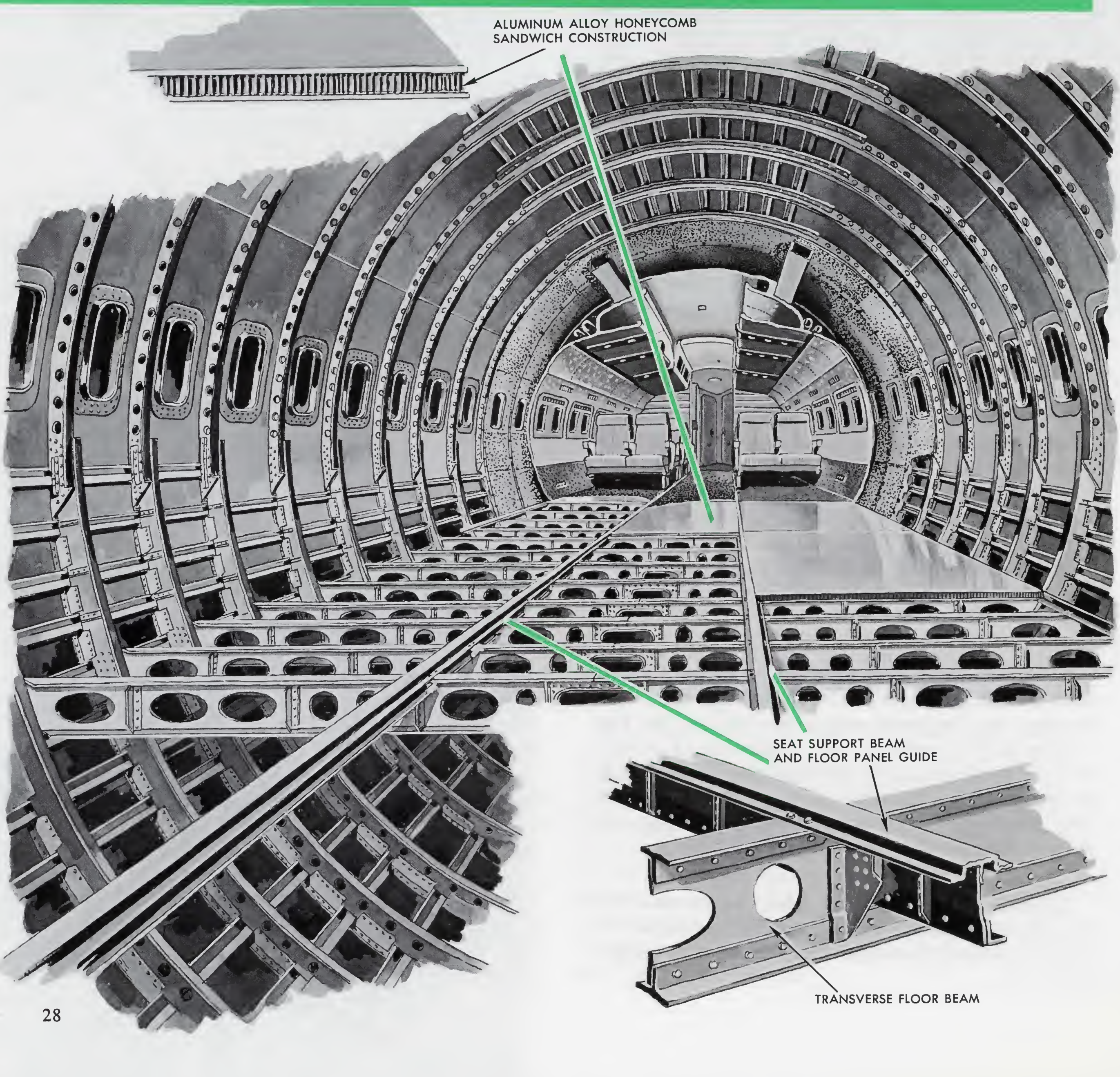
At the plane of symmetry on the fuselage bottom, a heavy built-up keel member insures structural continuity in the region where the normal fuselage structure is interrupted by the wheel wells and, to a lesser extent, by the wing center section.

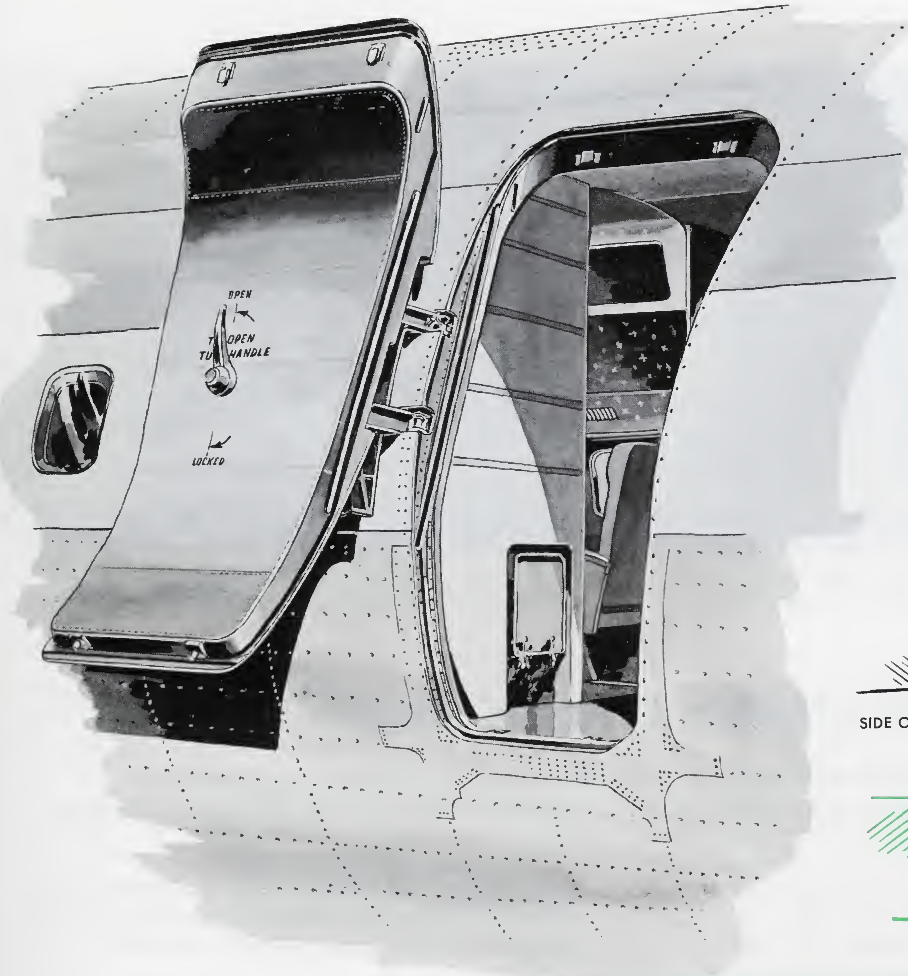
The under fuselage compartmentation aft of the weather-mapping radar nose includes the nose wheel well, the electronic and electrical sections, the forward cargo area, the air conditioning system (under the wing center section), the main landing gear wells, the hydraulic-pneumatic section, and the rear cargo compartment, in that order.

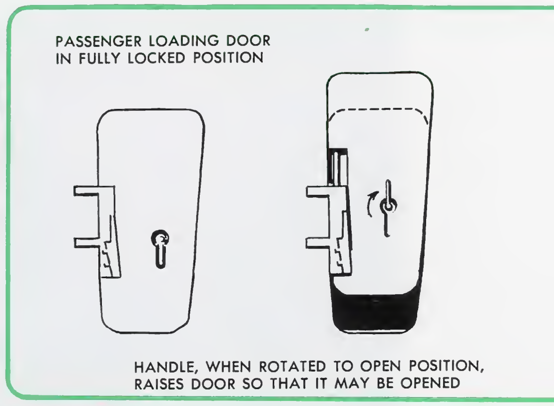
The cabin floor of aluminum alloy honeycomb sandwich construction is supported by transverse floor beams at each frame. A more resilient belly structure for wheels-up landing is achieved by the elimination of vertical members to support these floor beams. Use of vertical members could transmit shock to the cabin floor structure at the time of a wheels-up landing.

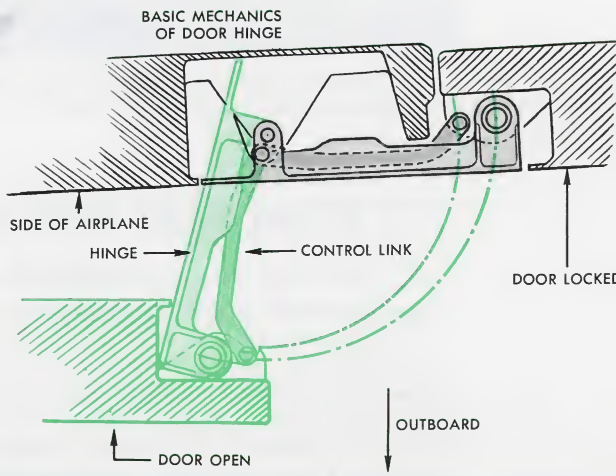
Another feature to be incorporated in the Convair 880 fuselage includes a passenger loading door whose

DETAIL OF CONVAIR "880" FLOOR STRUCTURE









FAIL-SAFE DOOR DESIGN for the "880"

mandatory design requirements incorporate adoption of the following safety features:

1. The door is of the plug-type, and does not depend on latches to restrain it from outward movement under any flight or cabin pressure condition. Increasing cabin pressure acts to increase the security and retention of the door.

2. The door hinges are designed to stow the door externally, well out of the entrance, in the open position.

3. The door can be opened from inside or outside, even though persons may be crowding against door from the inside.

4. The means of opening is simple, and is so arranged and marked that the door can be readily opened, even in darkness.

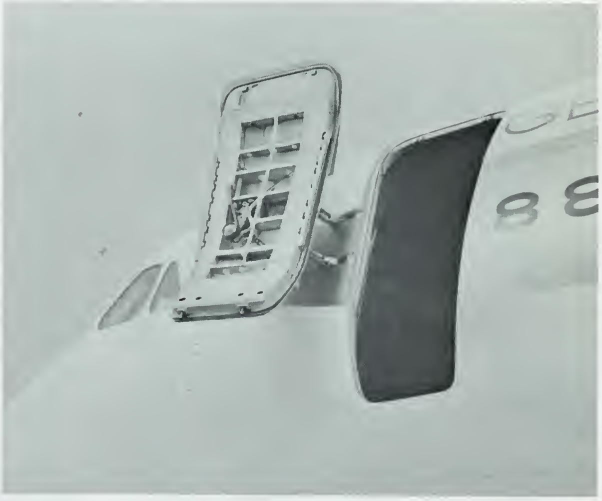
5. Provisions are made to minimize the possibility of jamming the door as a result of icing conditions, seal vulcanization, or fuselage damage due to minor crash landing. This is required because openings normally used for passengers also serve as emergency exits.

6. The door is capable of being operated by one person under any wind condition normally encountered in ground operations.

The "880" door is of an upward-sliding, side-hinged configuration. The edge adjacent to the hinge and the opposite edge are slanted to form a wedge-shaped door narrower at the bottom than at the top. Shear ledges along each edge of the door fit in recesses in the opening frame and are the load-carrying members. A mechanism incorporating a door weight counterbalance spring, actuated by the handle, provides the initial upward motion of the door. Hinges located at the forward edge of the door control the door during opening.

To open, the operator rotates the handle to the "open" position. This slides the door upward parallel to the hinge line. In this position, the shear ledges along the aft door edge will clear the mating recesses. The door can then be swung open, allowing the shear ledges adjacent to the hinge to rotate out of their mating recesses.

Door nearly closed on parallel hinge. When fully closed, door, hinge, and handle are flush.



Passenger door in fully raised, open position. Trim is removed to show operating mechanism.

Convair 880/990 Cabin Door Sealer

. . . Fail-safe cabin pressurization in the Convair 880/990 jet airliners is assured with development of two unique features — the plug-type door and the Convair Flex-Support Seal . . .

Because the "880" is designed to fly at higher altitudes and employs higher cabin pressurization, entirely new passenger entry and service doors were designed. These doors use a double-hinge principle. The hinges are completely flush when the doors are closed so that the door and its hinges contour smoothly into the fuselage shape. On one hinge line of the double hinge, the door is arranged so that it slides upward. The main passenger door, for instance, has a nine-inch movement in an upward direction as the first action in releasing the door from its fully locked position. When open, the door is parallel with the fuselage.

The doors are contoured to fit the fuselage curvature, but are wedge-shaped in plan form. This wedge shape, plus an upward sliding motion, permits the doors to be wedged, or more truly "plugged," into the door frame. The door and the door frame have long tracks along their sides which engage when the door is lowered, and disengage when the door is raised. Additionally, at the top of the door, two T-shaped members engage T-shaped slots on the upper door frame; at the bottom, two pins on the door engage holes in the door sill. The side tracks, the T-shaped engaging members at the top, and the pins at the bottom of the door serve to transmit the pressurization loads on the door to the fuselage. This door design precludes the possibility of the door opening under any normal flight condition.

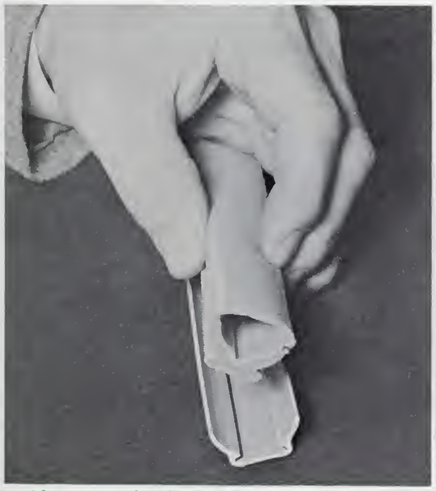
These unique fuselage entrance and service doors will be sealed under pressurized flight conditions by the Convair Flex-Support, self energized, bulb-diapnragm seal. The seal is a new concept in fail-safe high-pressure sealing and is in step with other advance design features embodied in the Convair 880 and 990.

The seal is constructed of high-strength silicone rubber, reinforced with two-way stretch dacron fabric; an inner and outer pressure wall precludes loss of pressurization in the event of unforeseen damage to the outer wall.

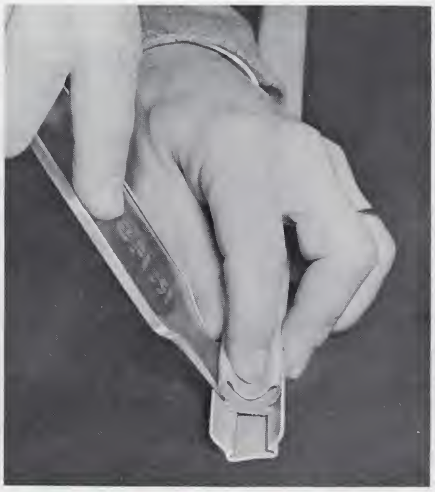
The Flex-Support, a fail-safe feature, is integrally molded within the seal to eliminate the possibility of seal collapse. This flexible spring wire supports the sidewalls of the seal against lateral pressure loads, when pressurized, to assure positive alignment between the seal diaphragming crown and the fuselage striker. The fuselage striker is placed opposite the center line of the seal so that it will depress the seal crown when the door slides closed.

The seal is automatically self-energized by the difference in pressure between the cabin and atmosphere through a series of small vent holes between the convolutions of the flex support on the cabin side of the seal. This permits cabin air pressure to enter the seal and to diaphragm the stretchable crown firmly against the fuselage striker. The higher the pressure differential, the tighter the seal presses against the striker. Then, when pressure differential is equalized, the seal relaxes, and wear from the sliding and wiping action of the door is minimized.

Design of the door structure is such that positioning of the seal retainer in various convolutions was



Shown is bulb-diaphragm door seal and extruded door seal retainer.



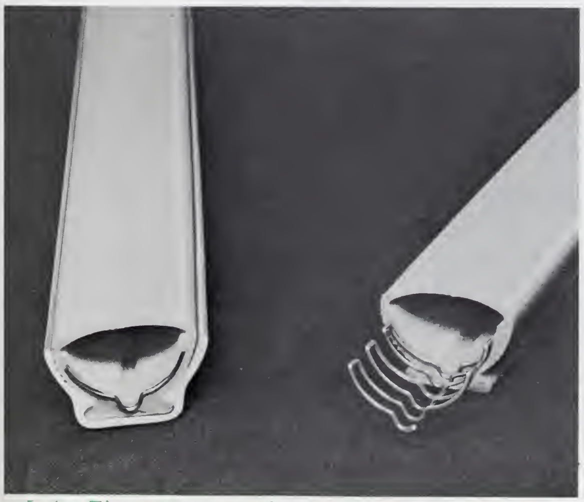
Bulb-diaphragm door seal is started in retainer with blunt plastic tool.

Shoulders of the seal are worked in progressively along the retainer.

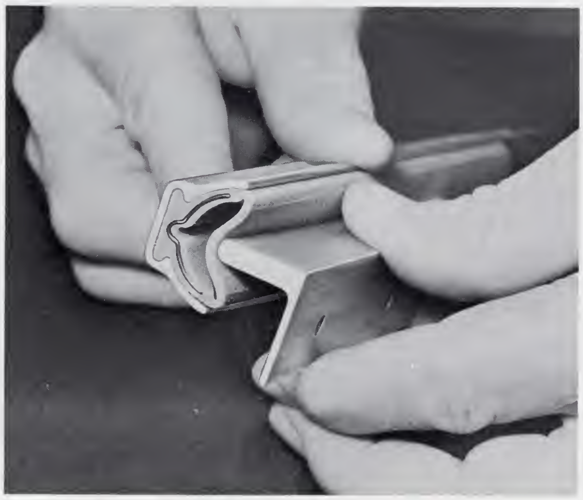
necessary to align the seal crown with the fuselage striker so as to effect positive sealing when the door is closed; yet, at the same time it must clear the fuselage striker and track structure as the door moves upward nine inches before opening. These conditions are easily accommodated by the new seal because although the "Flex Support" gives the seal a stiffened cross-section and proof against lateral pressure loads, it remains extremely flexible in the longitudinal direction to facilitate installation on highly contoured surfaces.

More than 6000 wiping action cycles, conducted concurrently with pressure cycling tests to 8.6 psi, have proved that the new Convair flex-support, self-energized, bulb-diaphragm door seals will meet all operational requirements. The fail-safe qualities of the seal were checked by deliberately cutting the seal while it was pressurized to 8.6 psi. Little pressure drop was noted. In an attempt to "fail" the seal, the cut was increased to a triangular hole. The seal continued to hold tightly against the striker at all points because of the steel flex-support, with no indication of seal collapse, blow-by, or explosive decompression. There was some bleed-off at the point of puncture. To further test the seal, it was placed on a high-pressure test stand and subjected to the full test gage limit of 35 psi without failing.

For comparative purposes, the identical tests were performed on a variety of other seals. The eventual failure of the seals provided conclusive proof of the superiority of the "Flex-Support," self-energized, bulb-diaphragm seal.



Left: Flex-support seal in section of extrusion. Right: Door seal with flex-support wire exposed.



Contact between flex-support seal and striker. Cabin pressure "wraps" seal around striker.

Low Temperature Door Tests
Convair 880

Convair structures lab engineers recently conducted a series of tests to prove the operating capabilities of the main entrance door of the Convair 880 under varying icing conditions.

A plywood "cold" box, 90 inches high by 60 inches wide, was constructed and formed to fit the contour of the fuselage in the area of the aft main entrance door. The box was placed over the door and the area sealed; CO_2 was pumped in to lower the temperature and freeze the area covered by the box. During some of the tests, water was sprayed into the box, resulting in an approximate 3/16-inch thick coating of ice over the door edges.

Thermocouples were attached to the top and bottom of the door on the outer skin, and to the top of the door on the inside structure. By monitoring the thermocouples, with a temperature controller-indicator, the "weather" inside the box could be varied to simulate different conditions. Strain gauges were fitted to the door handle, and measurements were taken of the force required to open the door.

The results of the tests proved that under severe weather conditions, with outside temperatures far below 0°F, the door of the Convair jet airliner could be opened from the inside.

To insure successful operation of the door under frozen conditions, it is recommended that a low-temperature grease be applied on the slide tube of the door. All-purpose low-temperature grease MIL-G-7421 (Convair Material No. 273445) was determined by the tests to meet proper requirements for "880" door lubrication.

STRUCTURAL INTEGRITY of the CONVAIR 880 WING

"Built-in safety" is one of the most important factors in the design and subsequent operation of an airplane. Configuration, speed, comfort, and ease of maintenance all contribute to saleability, performance, and acceptance of an airplane, but without assured structural safety, it may as well remain in the planning stage.

A fail-safe design is one that will allow surrounding structure to assume the load of a failed member in the event that fatigue failure or other failure takes place.

Fatigue failure is the reaction of metals to repetitive stress. For example, fatigue failure is experienced any time a wire is bent back and forth in an effort to break it in two. If a load, which induces tension stress, is repeatedly applied, failure will occur at considerably less than the ultimate strength of the material. The higher the applied load, the fewer times it can be applied before the material will fail.

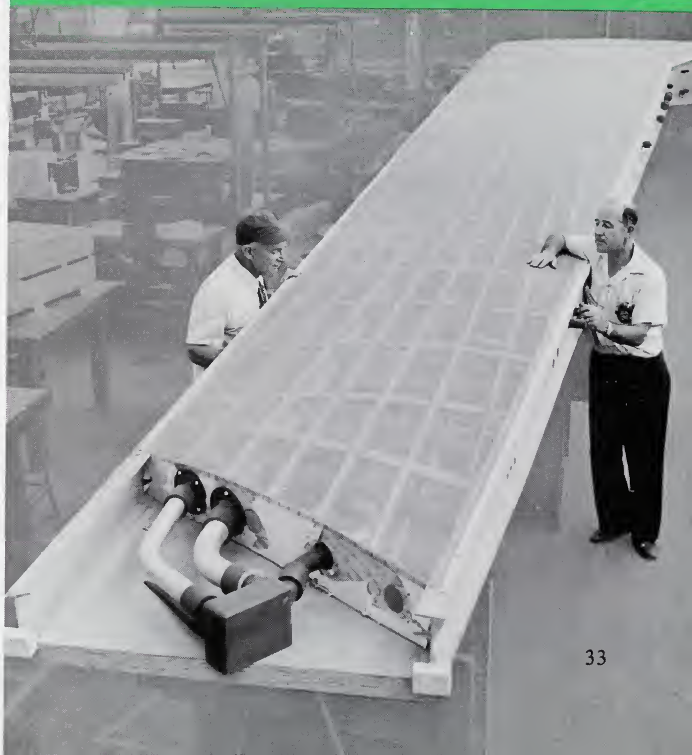
In the design of the Convair 880 jet transport, scheduled for delivery in 1959, Convair has incorporated fail-safe and fatigue-resistant features on a scale unparalleled in the history of aircraft manufacture. These features are based on the concept of "co-existence" of all structural members; thus should any single unit fail, structural integrity is not jeopardized.

The "880" wing is a culmination of all the features of the Convair-Liners and F-102 Interceptor, plus the increased knowledge gained through the most extensive testing of complete wings ever undertaken by an aircraft manufacturer. The details of design, such as rivet patterns, splices, and access doors, reflect the knowledge gained from extensive wing panel fatigue tests conducted by Convair during the past several years. These tests of actual structural assemblies furnished information concerning the interaction of structural elements—information that cannot be obtained from tests of smaller components.

Because the Convair 880 wing follows the general design plan of its predecessors—the Convair-Liners and the F-102 Interceptor—design improvements developed during the many test programs on these airplanes have been transmitted directly to the new airplane.

In one of these tests, a Convair-Liner wing panel, being static-tested at the end of the long fatigue testing program, withstood more than the required fail-safe load, with nearly one-third of the lower

Full-scale structural mockup of wing box section provides pattern for "880" wing fabrication.



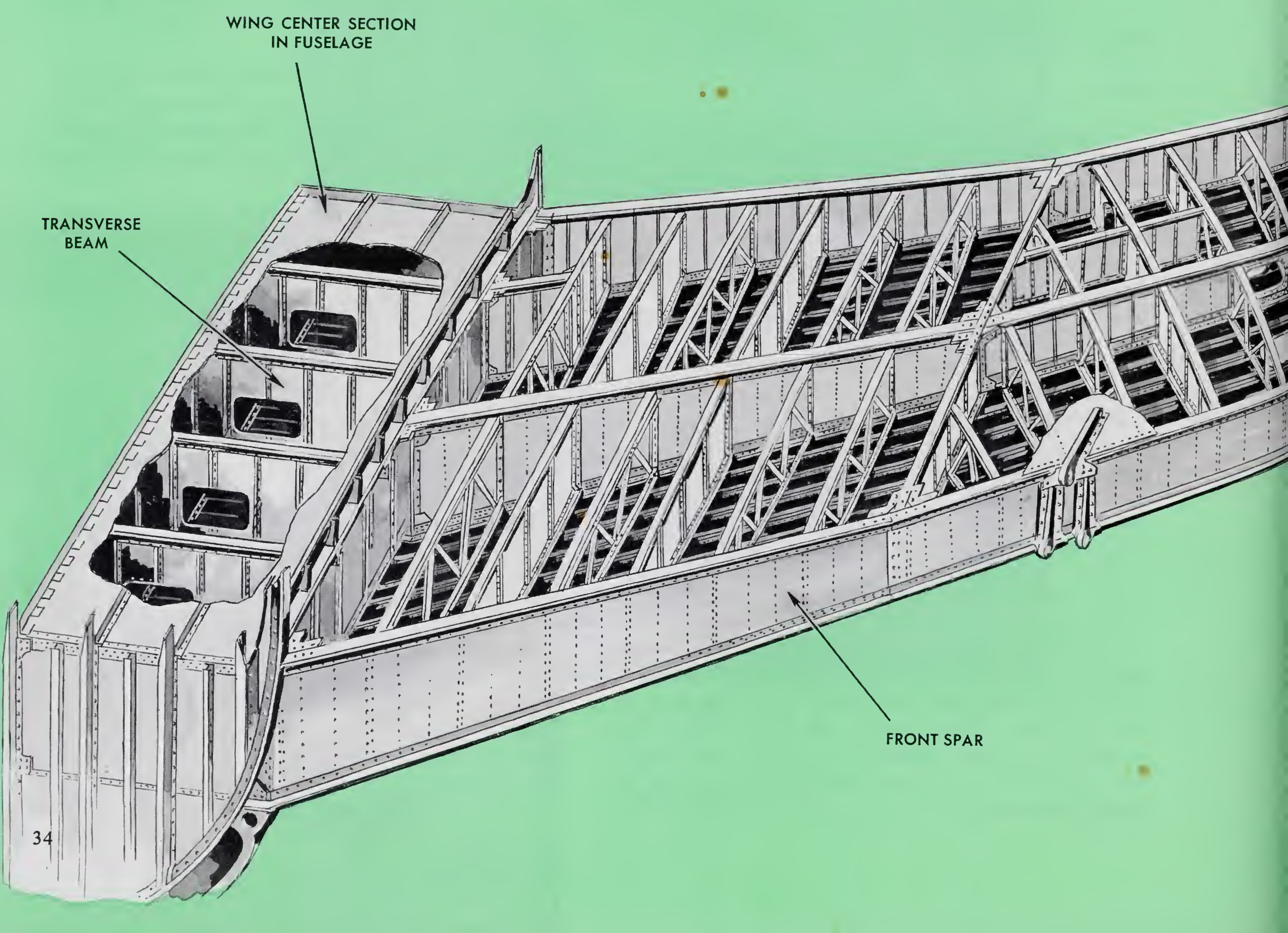
surface cracked through. In other tests, stringers and spar rails, sawed part way through in advance, were induced to fail under loads up to 71 per cent of ultimate design without producing failure of skin, spar webs, or other structure. Since the "880" wing follows the general design plan of other Convair aircraft, design improvements developed during these wing test programs will be incorporated in the "880" design.

The primary wing structure of the Convair 880 is a box beam consisting of spars, plating, and stringers, similar to the type used on current Convair aircraft. This arrangement distributes the structural load among many relatively small members, minimizing the importance of each.

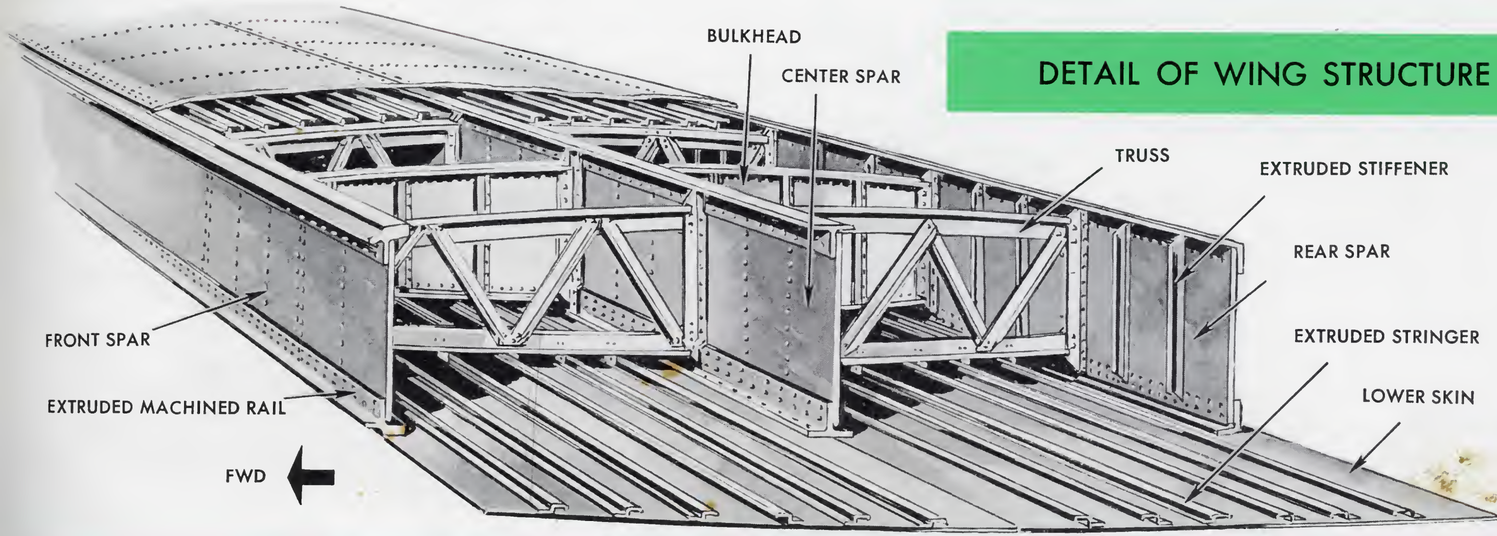
The "box section" wing incorporates three built-up type spars, plate-stringer skin panels, and built-up bulkheads. The spars have extruded machined rails, extruded stiffeners, and roll-tapered webs. They are assembled with rivets, and a special Scotchweld bonding method is used in the faying surfaces of all parts.

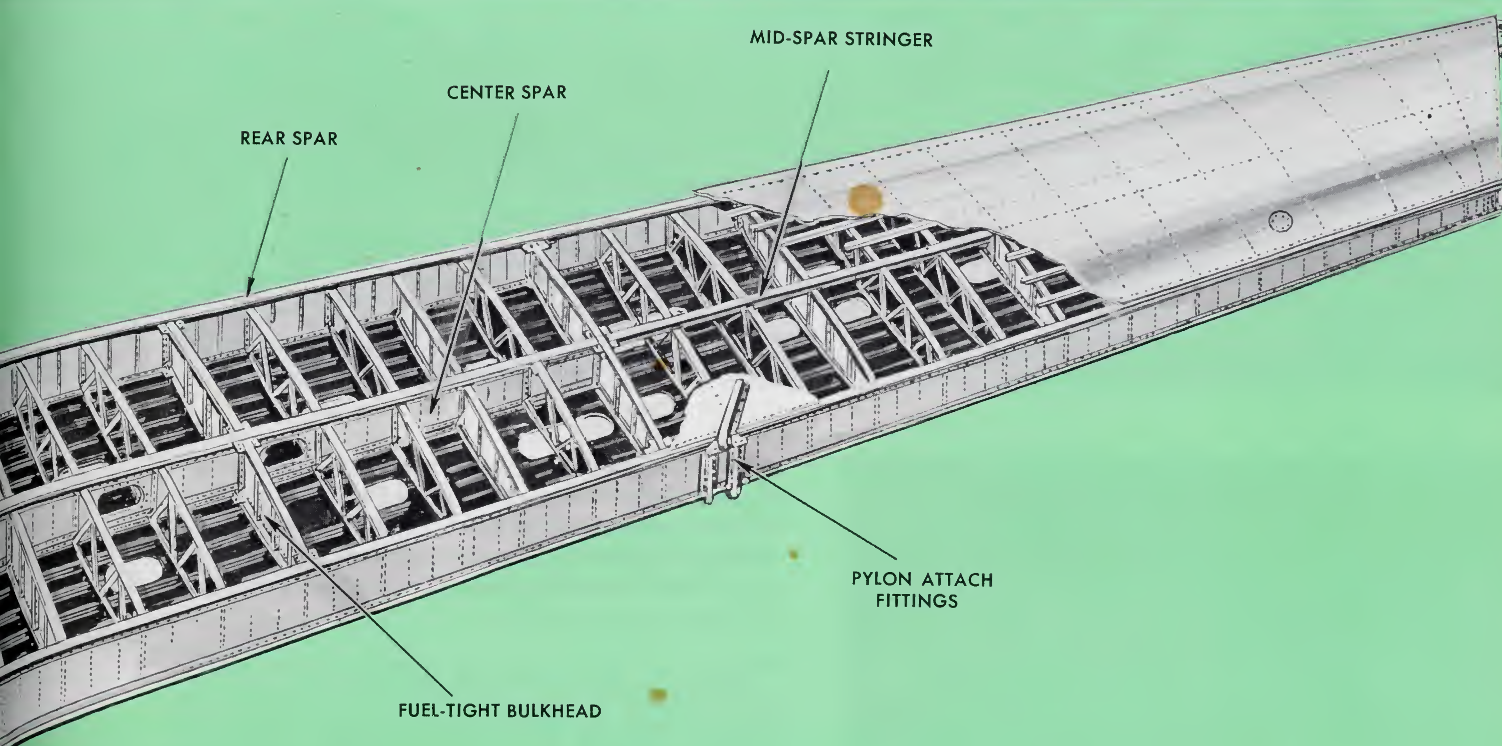
From the fuselage to a point outboard of the outboard engine, a three-spar arrangement is utilized . . . front, center, and rear spars. The purpose of the three-spar arrangement is to provide a fail-safe structure in the event any one of the three spars should fail. The center spar in the thin "880" wing provides intermediate support for wing bulkheads. Outboard of the outer engine, only front and rear spars are used. In this area, trailing and leading edges are designed to provide a fail-safe structure.

BASIC "880" WING STRUCTURE



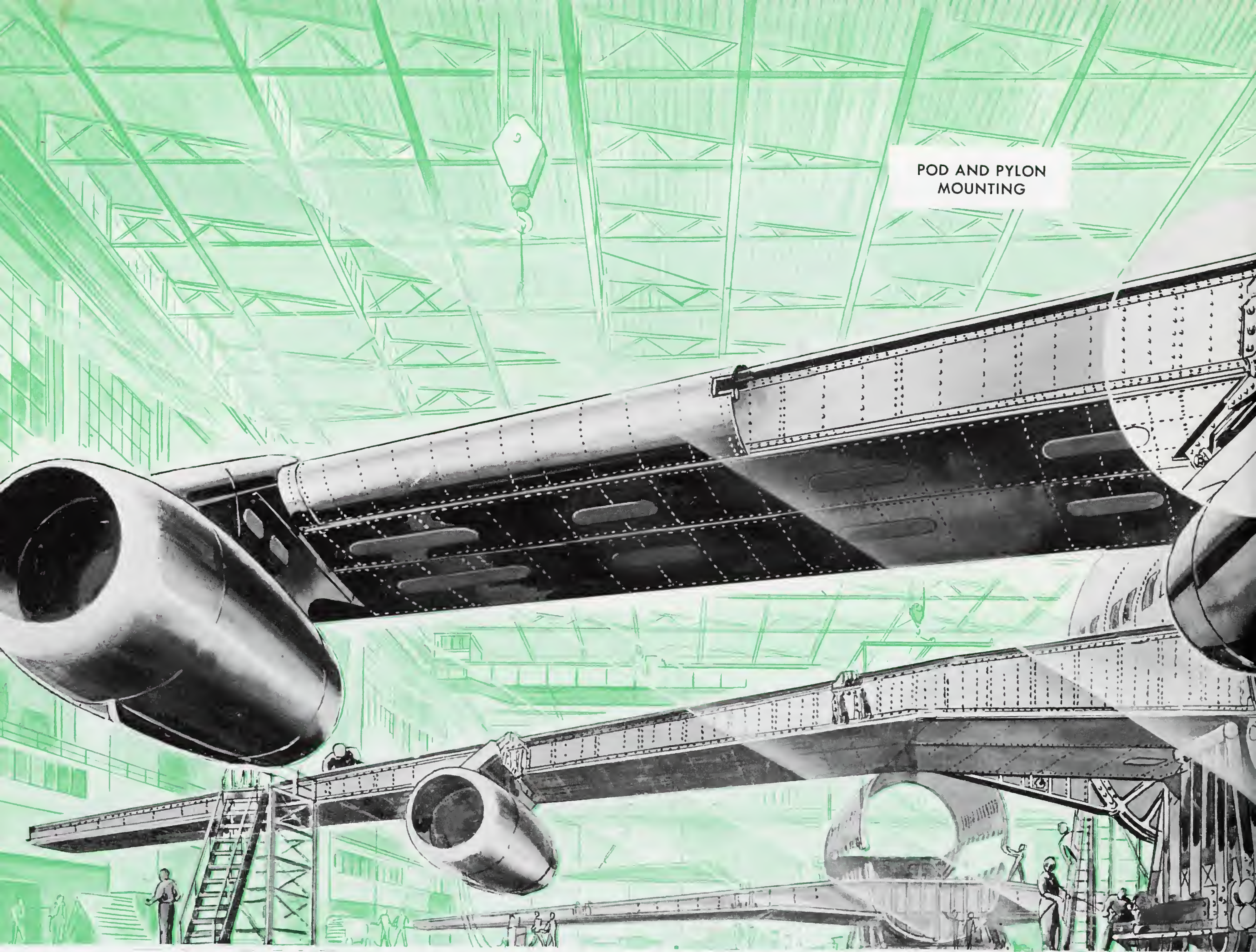
DETAIL OF WING STRUCTURE



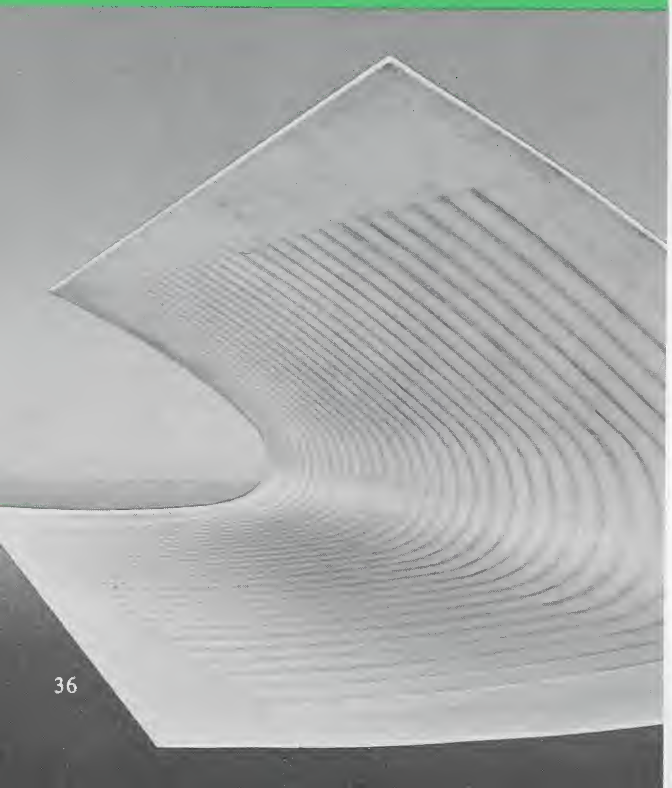


Stringers and upper spar caps are of 7178-T6, except for the front spar rail, which is of 2024-T4. This material was chosen for the front spar rail because contour of the wing provides relatively low front-spar stresses, and ductility of the material affords good resistance to forward-acting fuel loads in the integral tanks, in the event of sudden deceleration.

In addition to the three main spars in the wing, an auxiliary spar is used for support of the main landing gear. The auxiliary spar is supported jointly by the fuselage and wing structures. Detail design of the local structure is intended to permit the landing gear to break free of the wing without rupturing the fuel tanks in event of a crash landing. It is intended also that the pods and pylons break free of the wing without rupturing the fuel tank in a crash landing.



Wing leading edge skin is dynamically etched to provide channels for anti-icing heat.

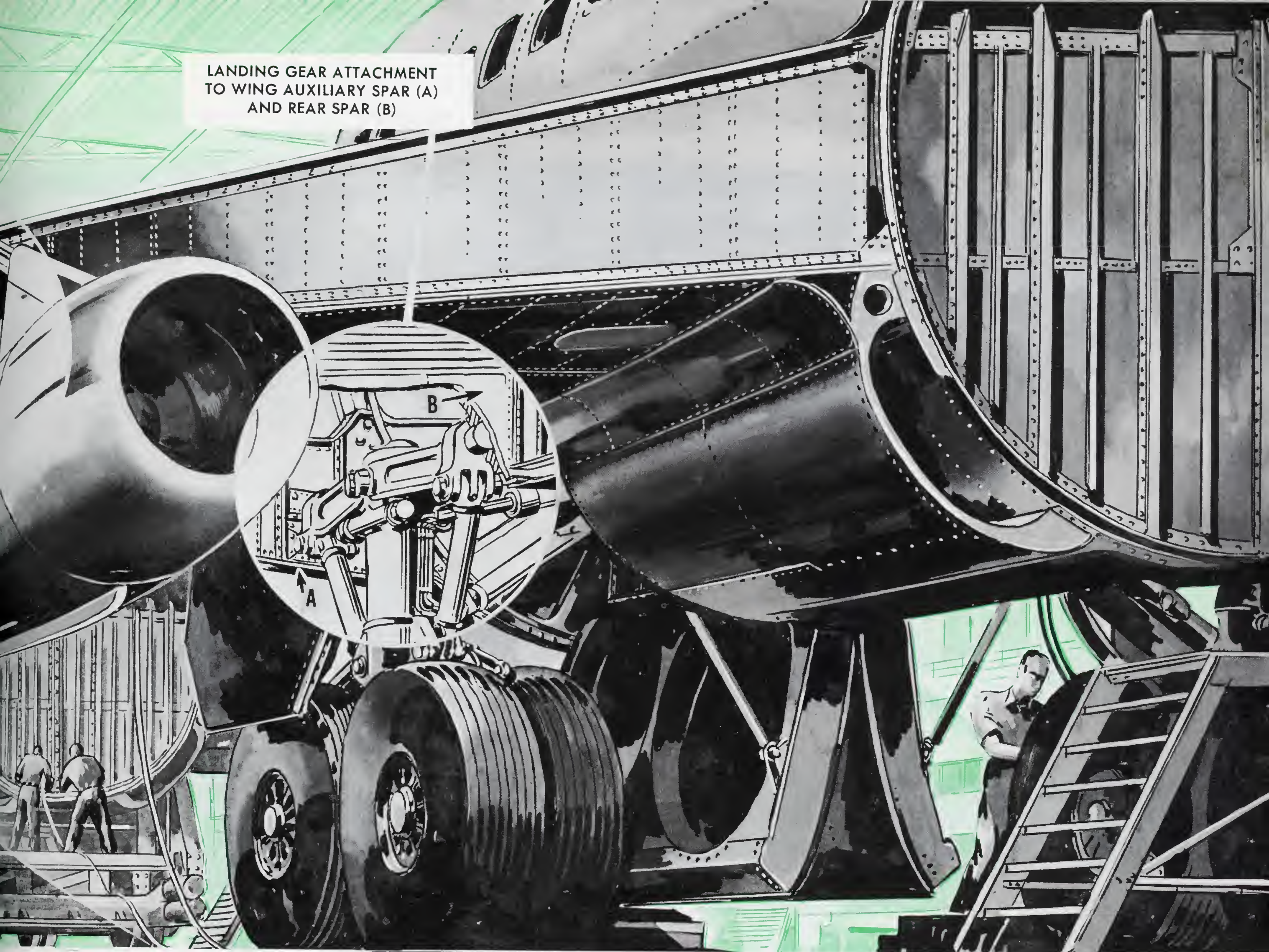


The wing center section beneath the fuselage incorporates four transverse beams between the front and rear spars. Each of these beams is bolted to the fuselage frames. Failure of any one of these beams or of the attaching frames will not jeopardize strength of the structure.

Splices in the Convair 880 wing have been developed through knowledge gained in cycling of the Convair 240 and 340 wings. Through additional cycling tests, each splice element in the "880" wing has been proved, thus insuring that all stringer ends, doors, doublers, and splice members will give long service life.

All wing bulkheads are of conventional web stiffener of truss type construction.

Skins on the upper and lower wing surfaces of the "880" are of heavier aluminum alloy than are those utilized on Convair-Liners. The high compression yield of 7178 aluminum alloy makes it suitable for the wing upper surface, where fatigue is not critical; the lower surface utilizes 2024, where fatigue is the primary consideration.

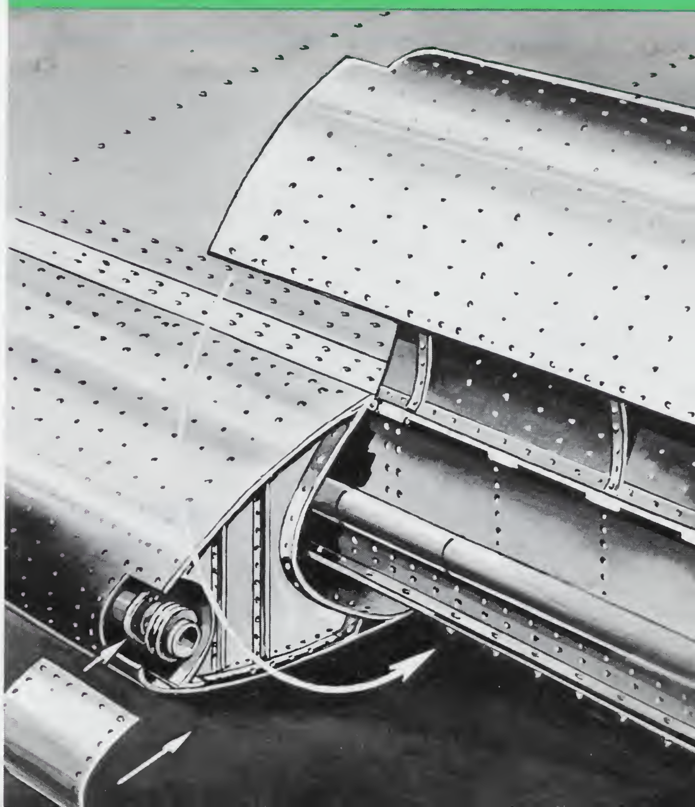


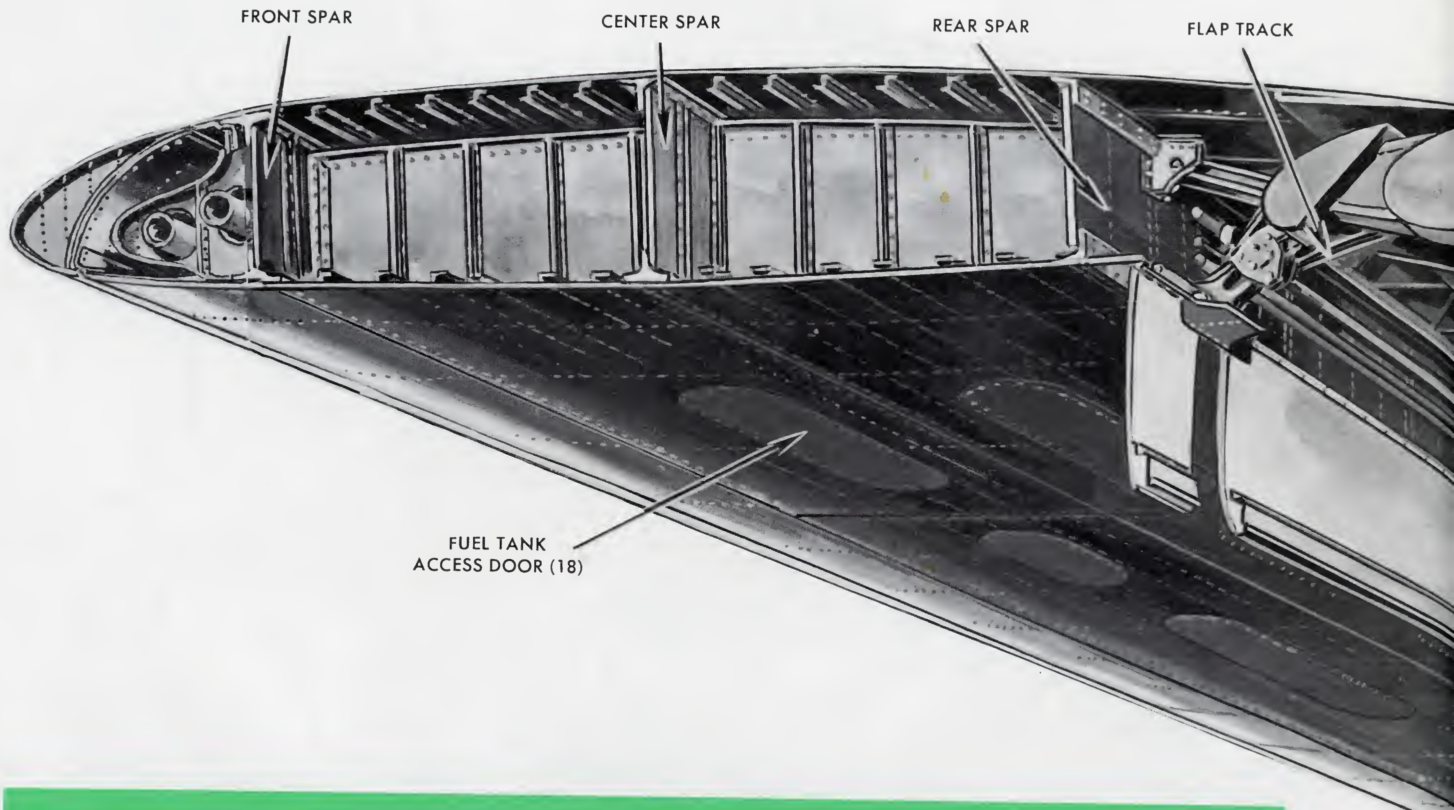
The skin on both surfaces is machine-tapered, varying in thickness, spanwise. This machine-taper provides the necessary structural strength at minimum weight in areas where it is needed. Extruded stringers are used on upper and lower surfaces.

The leading edges of the "880" wing are unique in structure and in the ability to provide anti-icing protection. There are two thicknesses of skin — a heavy gauge outer skin and a thin gauge inner skin. The outer skin, formed from material of approximately .100 inch thickness, is dynamically etched, after forming, to provide recesses approximately two inches wide and from .04 to .08 inch deep, chordwise around the leading edge. These recesses are separated by raised lands, ⅜ inch wide. The inner skin is wrapped inside the outer skin and the two are riveted together. The lands between recesses provide for attachment of the inner skin and nose ribs.

Heat, in the form of bleed air from the engine compressor, is fed into the channels, which are formed by the lands, through titanium tubes. The result is an almost perfect heat exchanger that has

Leading edge sections from outboard engine to fuselage are hinged for quick easy access.





WING LOWER SURFACE
SHOWING ACCESSIBILITY

proved 85 to 90 per cent efficient. Under limit cruise load tests, no wrinkles appeared on the leading edge structure, and a perfectly smooth surface was maintained up to design limit load.

The trailing edge, flaps, ailerons, and spoilers are of bonded honeycomb construction, developed to decrease the fatigue effects of sonic vibrations. This structure was developed after extensive testing in the facilities maintained by the test lab at Convair.

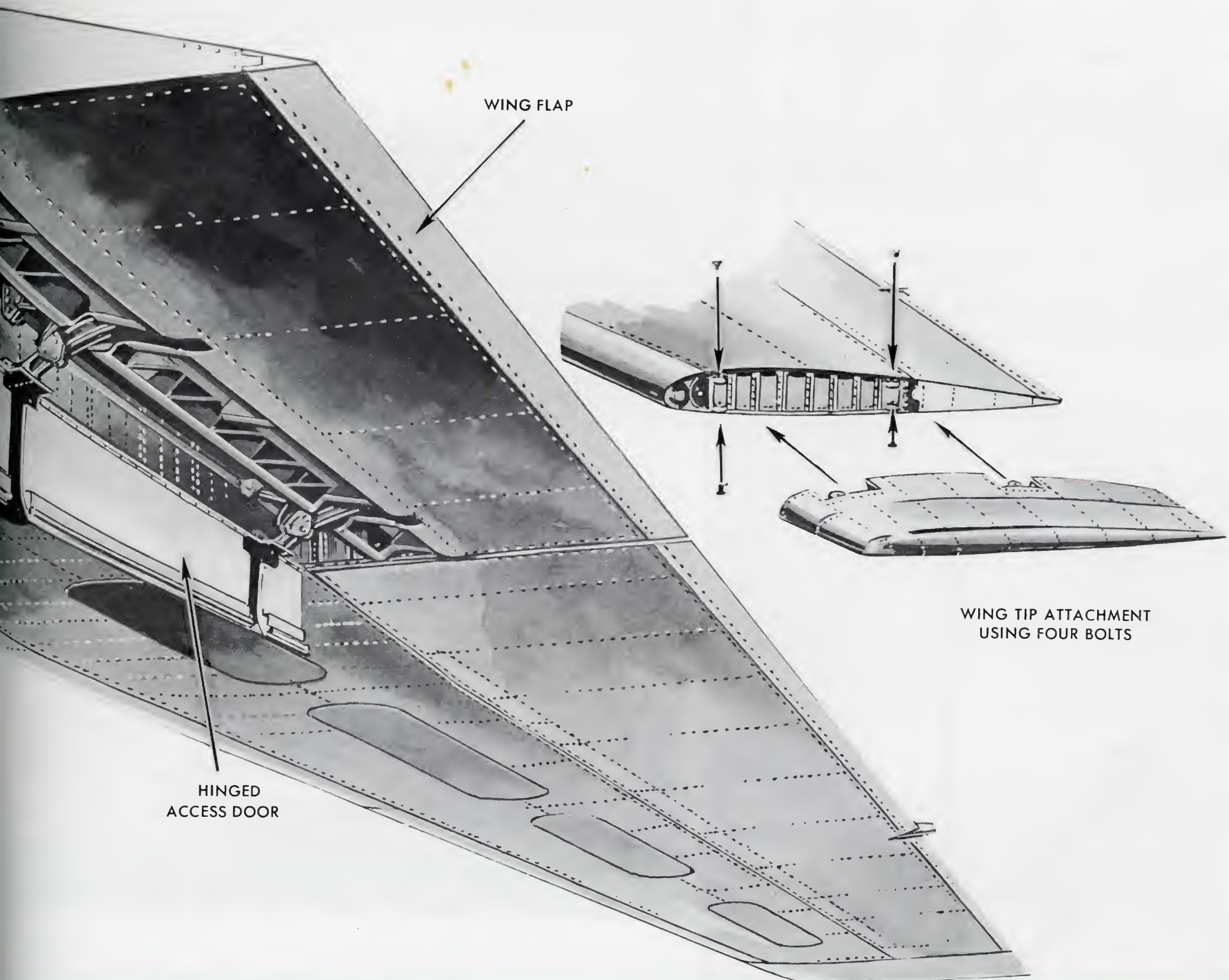
A siren for developing pressure impulses was used for development work on the honeycomb panels. The siren operates on the principle of compressed air passed through a plenum chamber to a siren motor, which converts compressed air power to sound power. From this stage, the sound is propagated by means of an acoustic matching horn, and then piped through a sonic tunnel. Power for the test program is provided by a 140-hp industrial engine driving an Allison supercharger turbine.

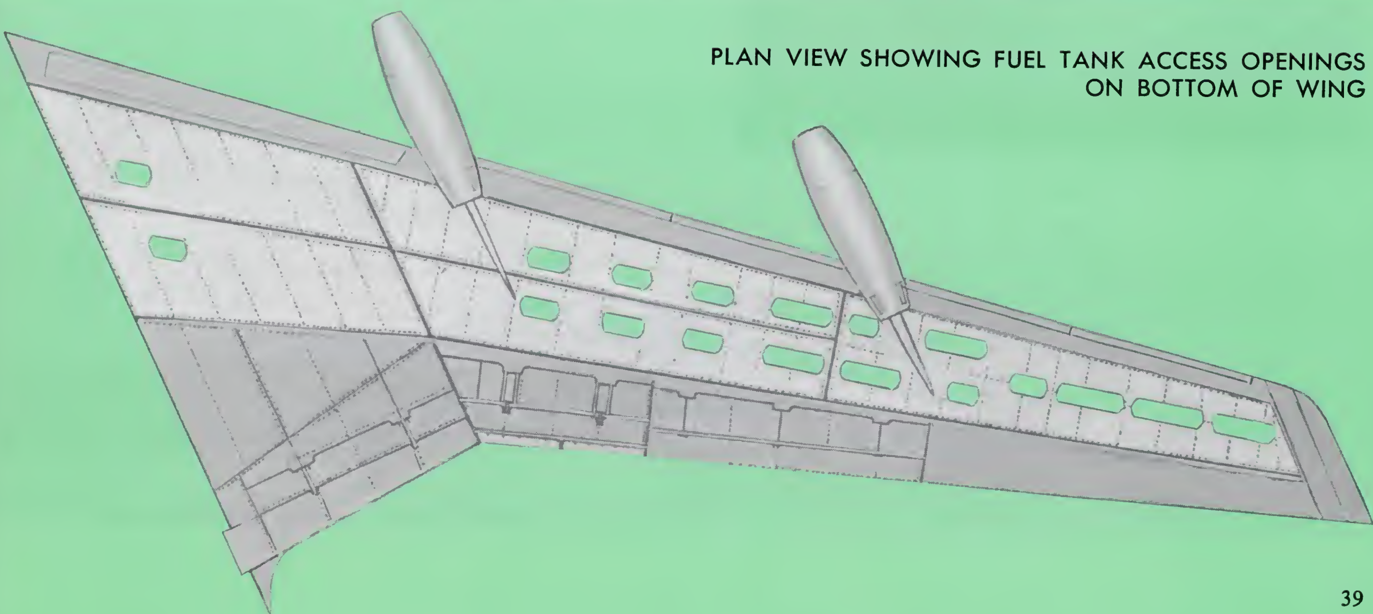
The test acoustic pressures generated by the siren result in 400 pounds or more dynamic drive over a test panel 22″ x 44″. These are accelerated test conditions and greatly exceed the sound pressures expected for Convair 880 operations.

Considerable attention has been given to accessibility for maintenance and inspection purposes. A full-size mockup of the wing was built for the express purpose of working out a combination of access doors, hand holes, and locations for equipment, so as to provide maximum accessibility with minimum effort.

The entire lower surface, forward of the flaps and aft of the fuel tank, is hinged to give access to equipment located along the rear spar. The leading edges from the outboard engine to the fuselage are hinged for quick, easy access and to prevent damage to leading edges during maintenance operations on equipment in the leading edges. The wing tips are attached with only four bolts and are easily removable.

Fail-safe design has been followed throughout the wing structural box, which incorporates the integral fuel tanks. The Scotchweld process, developed by Convair in cooperation with Minnesota Mining and Manufacturing Company, utilizes a metal-to-metal adhesive for fuel-tighting of structural members and skins in these areas.





PLAN VIEW SHOWING FUEL TANK ACCESS OPENINGS ON BOTTOM OF WING

In addition to conventional riveting at all joints and splices, Scotchweld adhesive provides "bonus" structural strength and increased fatigue resistance.

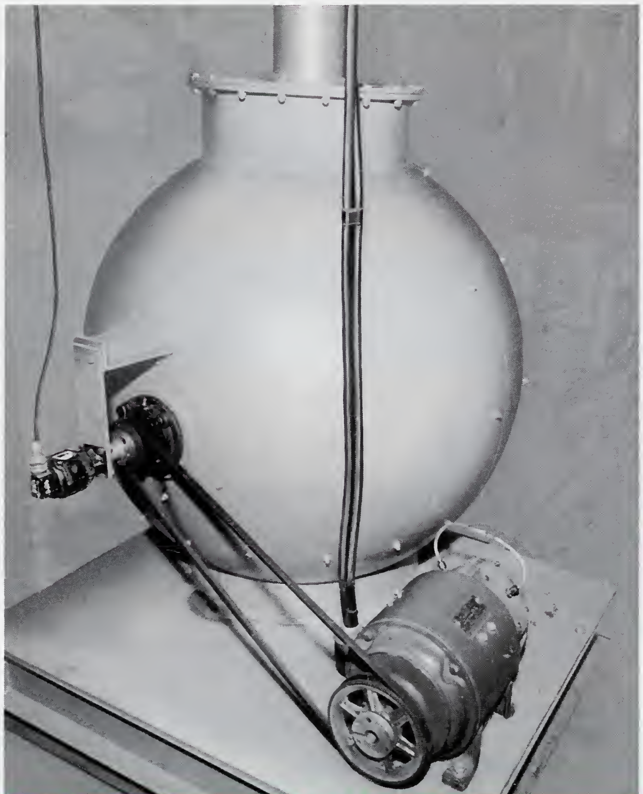
All surfaces of all parts inside the fuel tank are sprayed with a Scotchweld prime and cured at 150°F prior to assembly. This prime insures freedom from corrosion in the fuel tanks and on the faying surfaces of the tanks for the life of the structure.

The wing, after assembly, is placed in a large oven at a temperature of 320°F for one hour. After a cooling period, the adhesive becomes cured so that it is unaffected by fuels and chemicals.

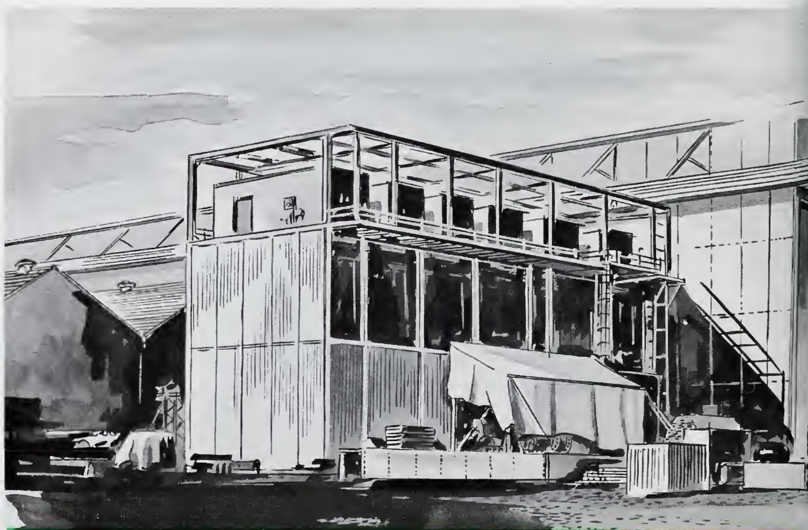
This is the same type leak-proof construction that is so successfully used on the Convair F-102 Interceptor. Tanks on the F-102 have proved to be virtually maintenance-free.

Other advantages of this type construction are: 1) it develops shear strengths of approximately 4000 psi; 2) it excludes fuel from all faying surface structure; 3) it "welds" the entire structure into a homogeneous mass that is leak-proof and maintenance-free.

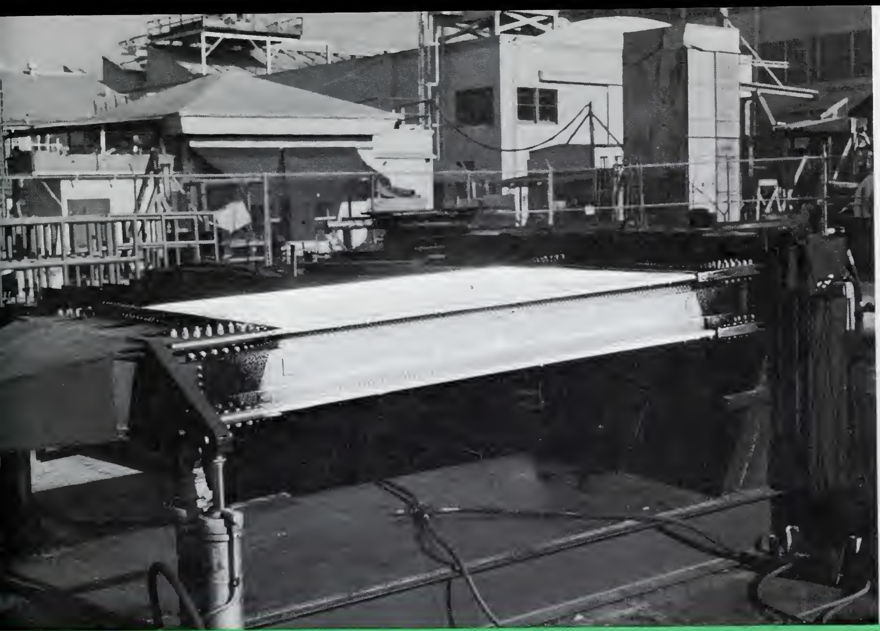
The Convair 880 wing integral fuel tank has been thoroughly tested, utilizing a full-scale section of the wing. This test specimen "wing" was a truly repre-



Siren is used to study high-energy sound effect on "880" honeycomb structures.



Nearing completion is Scotchweld oven used in leak-proof construction of wing fuel tanks.



Low-temperature test on wing panel produces frost and freezes fuel, but fails to create leaks.

Wing section in test facility is subjected to many loads to prove structural integrity.

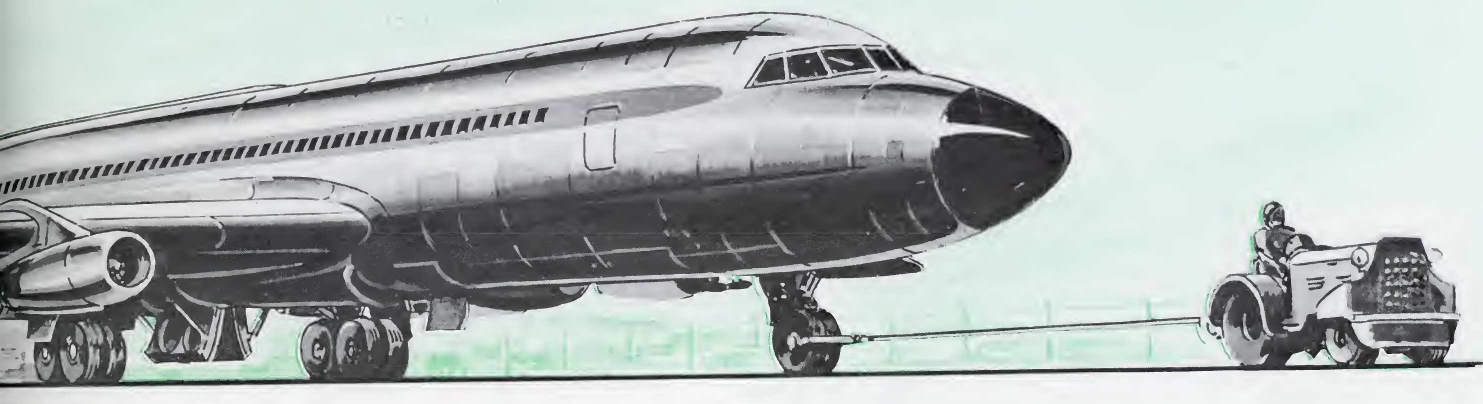
sentative section of the wing, embodying all proposed fasteners, structural elements, and other details as represented in the finished wing. The purpose of building this 20-foot test tank was to prove the integrity of the fuel tank and all materials used or proposed for use in the "880" tank.

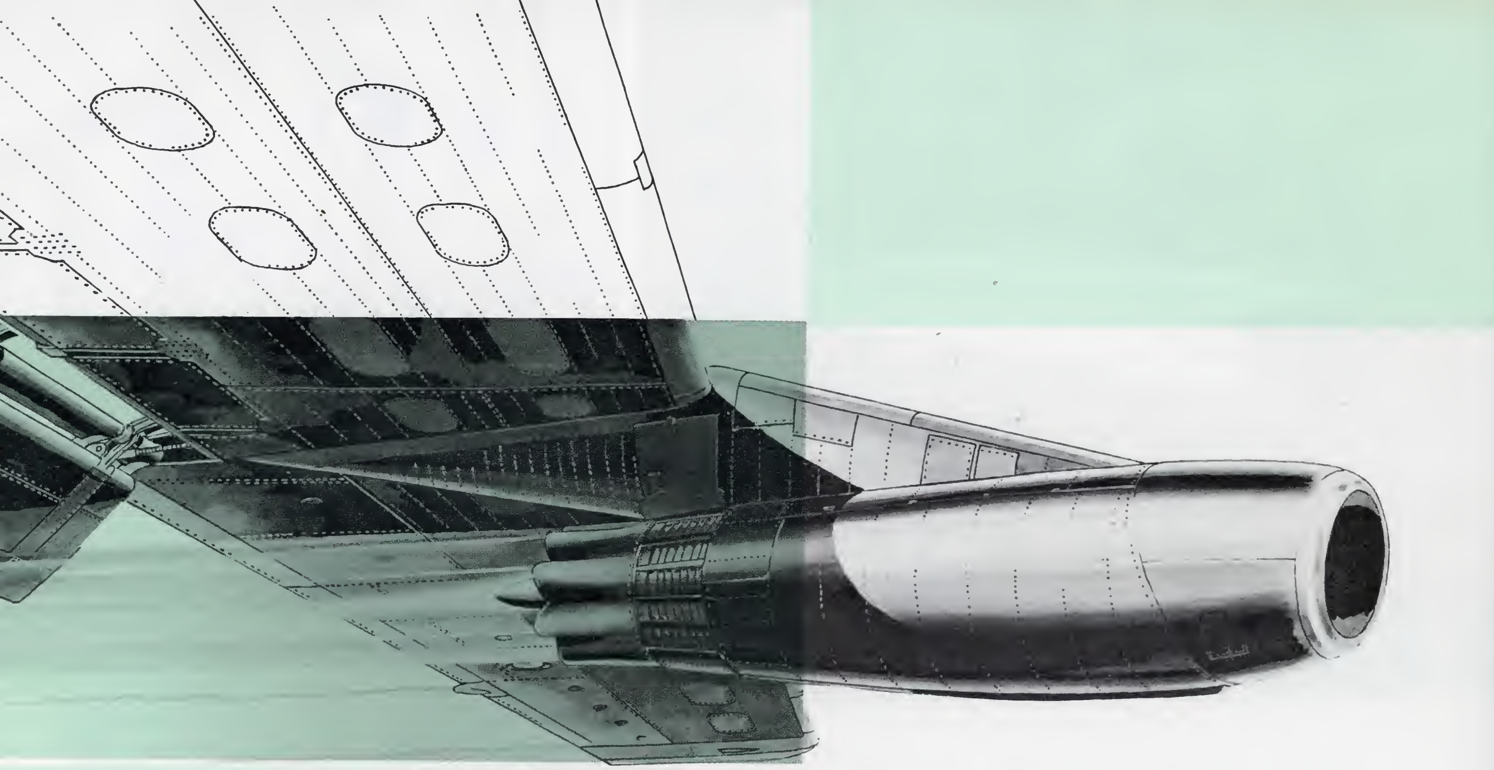
An exhaustive test program was instigated whereby a test tank was subjected to torsional, bending, and thermal stresses far in excess of expected service operating conditions. The tank, while filled with fuel and pressurized to 10 psi, was cycled through a load spectrum covering normal conditions encountered in airline operation.

The cycling program included a phase of low and high temperatures. The low-temperature cycling occurred at temperatures of –65°F and –70°F for a period of 48 hours. Near the conclusion of the cold tests, temperatures had to be moderated because of freezing of the fuel.

The high temperature tests followed, with temperatures ranging from 72°F (ambient) to 180°F for 48 hours. At the conclusion of this rigorous test program, the test log failed to show a single leak or even a stained rivet. No structural failure occurred and no evidence of the severity of the tests was noted.

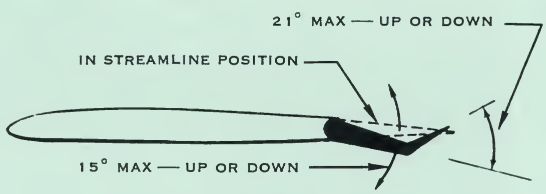
Considerable developmental testing of the "880" wing detail has already been completed. All tension critical joints and splices are being tested and will undergo fatigue cyclic loading patterns until failure. The valuable data gained from this fatigue test program are being reflected in the final product.



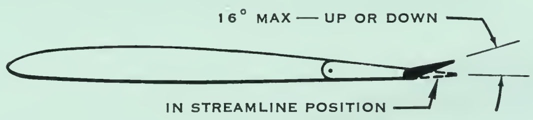


CONVAIR 880 WING FLIGHT CONTROLS

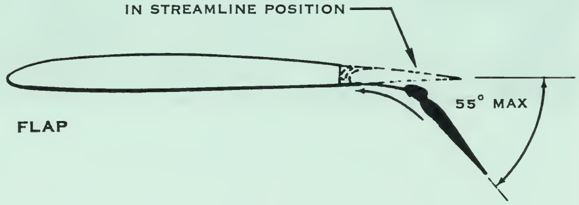
SPOILER (SPEEDBRAKE)



FLIGHT TAB CONTROLS — AILERON



TRIM TAB



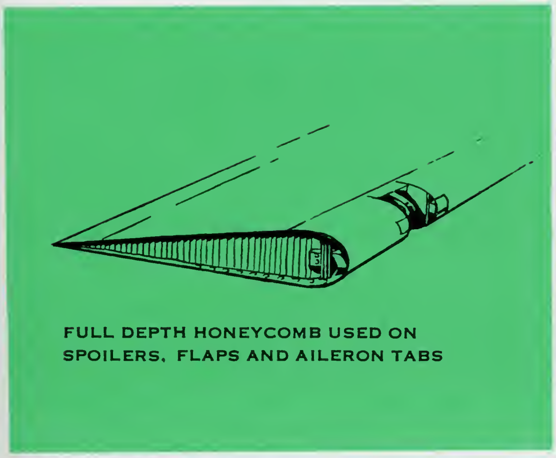
FLAP

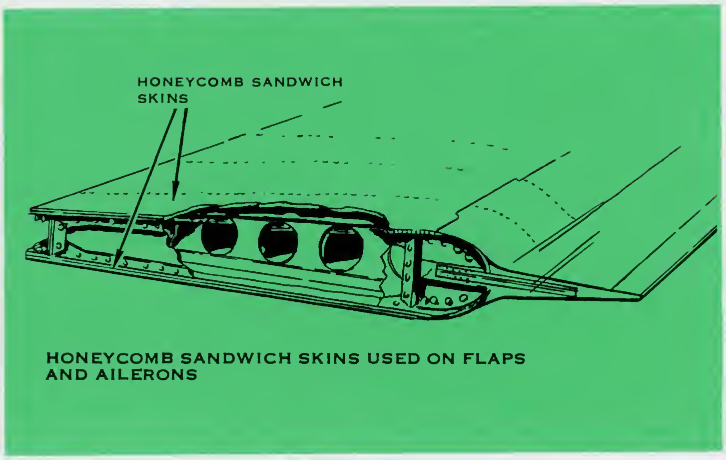
The wing flight controls in the Convair 880M differ markedly from the configuration that has for some years been standard on propeller-driven aircraft. Ailerons have been brought far inboard and are relatively small in area. Spoilers, mounted on the upper wing surface near the trailing edge, have taken over much of the aileron function and also may be operated as speedbrakes.

Flaps are double slotted type, each with a fore flap and main flap. One is inboard and one outboard of the aileron. Leading edge slats and Krueger flaps are extended along with the flaps for more effective lift at takeoff and landing speeds.

Aileron control is conventional, with the ailerons being moved by flight tabs connected directly to the control wheel by cable and push-pull linkages. In both aircraft, the spoilers are operated simultaneously with the ailerons, by means of a mixer assembly.

The entire wing trailing edge, including ailerons, spoilers, flaps, and controls, is of exceptionally rugged construction, to withstand the stresses of flight and the effects of high-energy sound. Convair tests have demonstrated that the wing surface aft of a jet engine may be subjected to sound pressures of .5 to 2.5 psi. To withstand such stresses, aluminum alloy honeycomb is used extensively; spoilers, fore flaps, the trailing edges of the flaps, and the aileron tabs are





all full-depth honeycomb. Upper and lower surfaces of flaps and ailerons are honeycomb sandwich skins, ½ inch thick in the flaps and ⅜ inch thick in the ailerons.

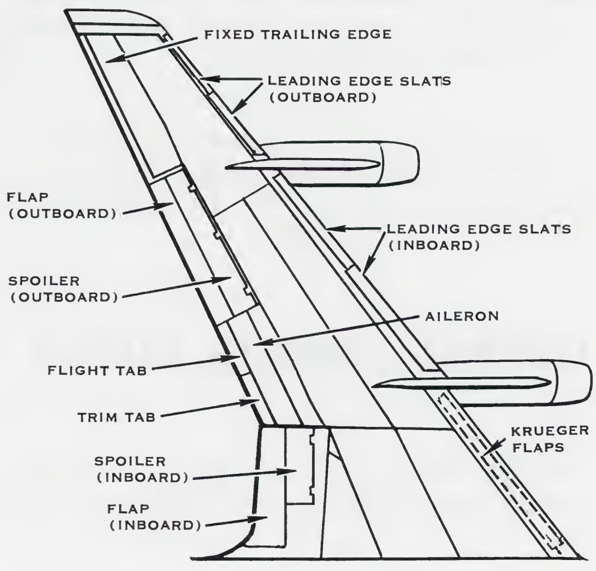
Honeycomb is used for strength and for its resistance to vibration damage. Not only the skin but the internal structure is designed for vibration resistance. Webs in the aileron and flap rigs, for example, are three-ply bonded metal laminates, in place of conventional single-thickness sheet.

Spoilers, flaps, and Krueger flaps are hydraulically actuated. Spoiler actuators are powered by both No. 1 and No. 2 hydraulic systems; either system alone provides sufficient power to operate them. Flaps and leading edge devices are operated by one hydraulic system, with the other system for backup. A dual cable system in the fuselage, and dual push-pull rods through the ailerons to the flight tabs, provide protection against failure of mechanical elements in the aileron control.

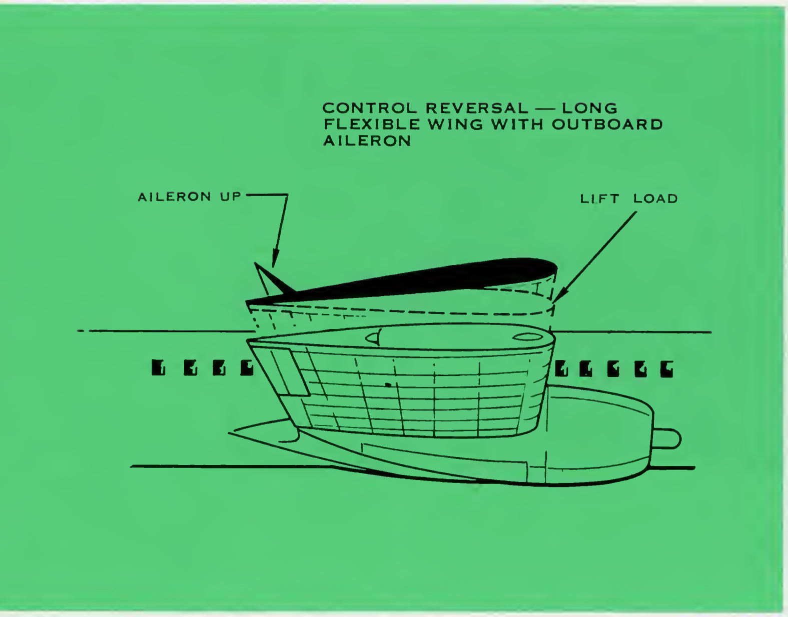
Safeguards and warning devices protect the pilot from inadvertent or overspeed actuation of the hydraulically-powered controls. Although the spoiler-speedbrakes may be extended at any speed, design of the actuators permits "blowdown" of the surfaces when airspeeds are too great.

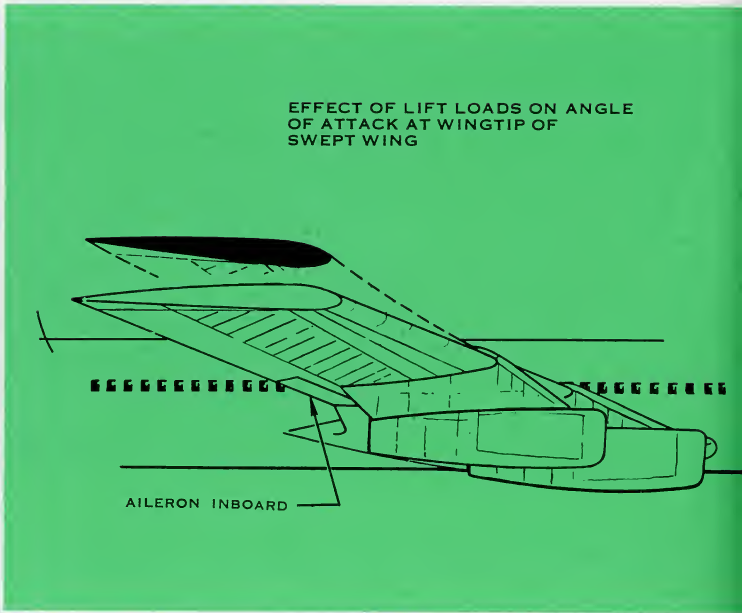
Speedbrake and flap control levers drop into detents at the retracted position and must be pulled up for extension, preventing inadvertent extension by bumping the levers. A flap position warning horn sounds should a takeoff be attempted in other than takeoff position.

The "fail-safe" principle governs design of the mechanical elements of the hydraulically-operated controls. Disconnection in a flap linkage, or excessive resistance in one wing, is prevented from causing



"880M" WING CONTROL SURFACE LOCATIONS





asymmetric flap extension by asymmetry switches at the ends of the flap torque shafts that cut off hydraulic power to the actuators. Any malfunction of one spoiler linkage leaves the other spoilers operable as required for stable flight. Should a disconnect occur in the spoiler system, the valves are springloaded to spoiler-down streamline position.

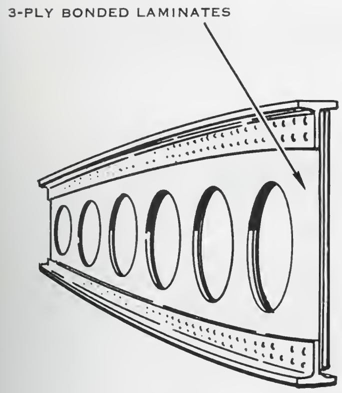
The aileron-spoiler interconnect is so designed as to permit the pilot to override the spoiler actuation mechanism if necessary, so that the airplane may be controlled by ailerons alone.

LATERAL CONTROL SYSTEM

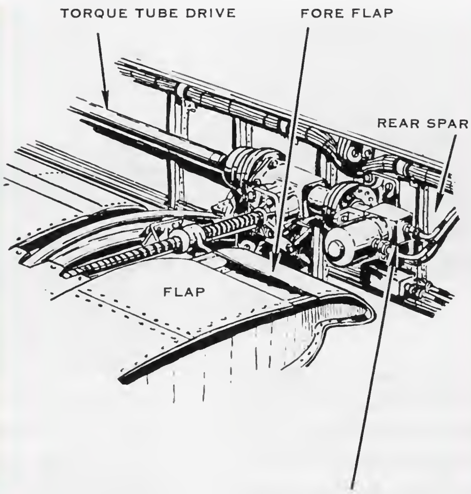
In the 880M the aileron, though designated a primary control, has dropped to a secondary role. Its principal functions are to provide a manual backup, capable of providing control in case of spoiler failure and to provide trim with a minimum of drag.

The spoilers furnish more than two-thirds of the roll control. This development in aircraft design is attributable to the greater wing loads at jet airplane speeds, and to the characteristics of a sharply swept-back wing.

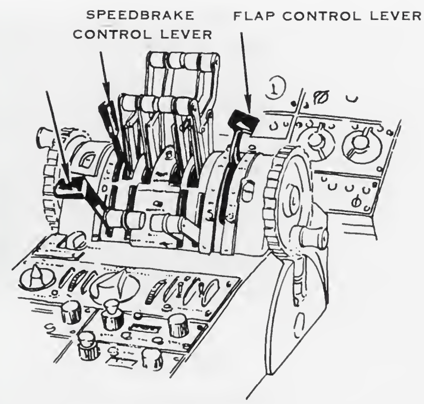
To be most effective in roll control with the least drag, ailerons have heretofore been placed in the outboard section of the wing. As is well known, modern aircraft wings are remarkably flexible. The flexure in a long, straight wing has, since airspeeds have approached the speed of sound, had a pronounced effect on the reliability of roll control response. A wingtip aileron, at high speeds, may function as a flight tab; that is, it may cause sufficient



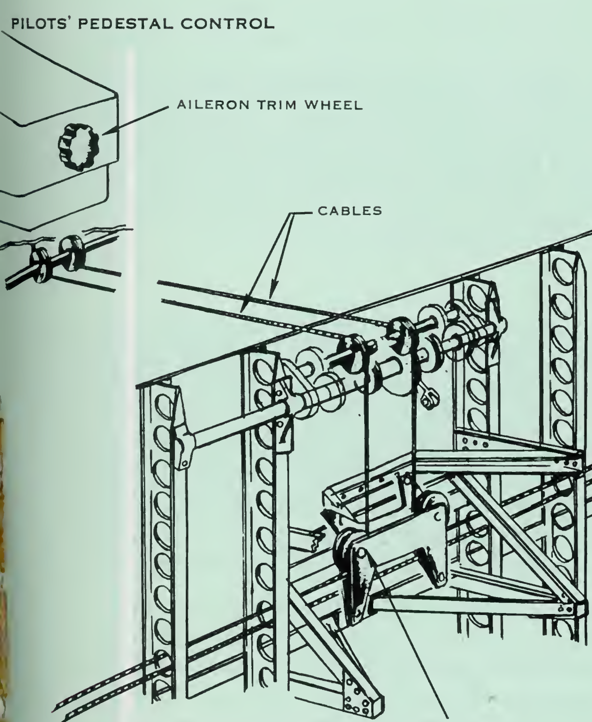
AMINATED WEBS OF AILERON AND FLAP RIBS



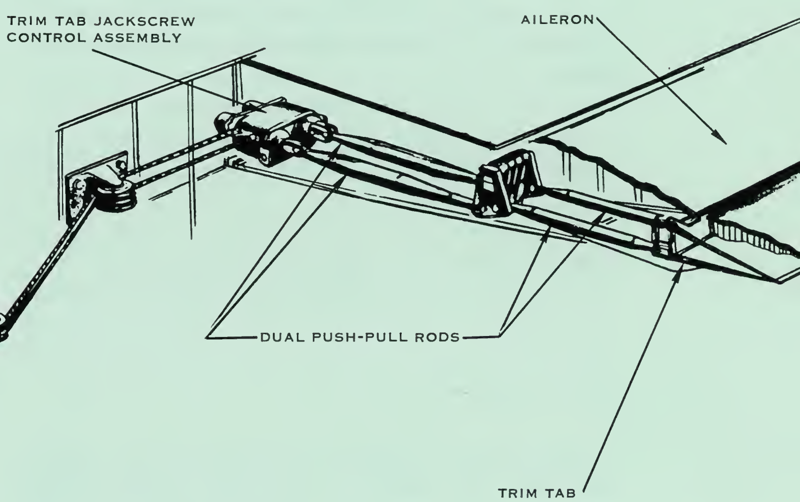
FLAP DRIVE ASYMMETRY SWITCH



SPEEDBRAKE AND FLAP CONTROLS



TRIM PULLEY & CABLES ON FWD BULKHEAD
OF HYDRAULIC COMPT



TRIM TAB MECHANISM IN WING

torque moment to twist the wing tip to the point of control reversal.

When a wing is swept back as it is in the present-day jet transports, the effect is aggravated. This may be understood by imagining the wing as a plane parallel to the line of flight. Bending of a swept wing from lift air loading will cause the wing tip not only to bend upward, but to present the top surface to the airstream so that the tip would tend to deflect downward. In actuality, such bending lowers wingtip angle of attack so that the tendency to control reversal is increased.

The "880" design criterion was that a sufficient amount of lateral correction, and sufficiently sensitive control, should be provided for a landing in a 25-knot crosswind. This is a high engineering standard and requires more roll moment than is practicably possible with ailerons alone, especially with the ailerons brought inboard far enough to be free from torsional reversal problems.

A spoiler, by its deflection action and by simultaneously lowering one wing's lift, does provide a large roll moment. The 880M spoilers are more than two feet wide and can be extended to 60° trailing-edge-up at any speed up to 200 knots IAS. Full extension is obtainable within two seconds; retraction is even faster.

The high force required for operation of the spoilers is provided by hydraulic piston actuators, two on each inboard spoiler and two on each of the two sections of the outboard spoiler. Each actuator is powered by both hydraulic systems. There is one dual selector valve for the inboard spoiler and one for the outboard, with mechanical followups to stop the flow to the actuators when the selected spoiler position is reached.

The selector valves are so designed that, when the aerodynamic load on the actuating pistons exceeds the hydraulic force holding the spoilers extended, the fluid flows back into the hydraulic systems. Should one of the hydraulic systems lose pressure, hinge moment will be reduced and blowdown will occur at lower speeds; but full deflection will still be possible at 150 knots IAS or below.

Trim control is provided in the aileron. The trim tab, approximately half the trailing edge of the aileron, is operated by a screwjack mechanism, connected by cables directly to a trim wheel on the pedestal. The trim tab may be moved 16° up or down; aileron travel is 15° up or down. The flight tab, which is the other half of the aileron trailing edge, may be moved 21° up or down. Its linkage with the flight compartment is explained in the description of the aileron-spoiler mixer assembly.

SPEEDBRAKE SYSTEM

Speedbrakes have not ordinarily been required on propeller aircraft because the propeller, when not exerting positive thrust, is an effective brake itself. However, some high-performance propeller-driven transports have found it necessary to drop the landing gear for deceleration purposes or for rapid descent at constant speed. The need for more drag is acute in jet aircraft. Besides having no propeller and being aerodynamically cleaner, a jet airplane in a holding pattern must stay at high altitude, and must be able to come down quickly without building up dive speeds. The common occasion for rapid deceleration is "gust penetration" — slowing down for turbulent air.

The 880M obtains the necessary drag from both landing gear and spoiler action. The spoilers, when used as speedbrakes, move up and down symmetrically and simultaneously. This control is by movement of a lever on the left-hand side of the pedestal beside the throttle levers.

Since the spoilers may be used for lateral control and as speedbrakes at the same time, the mixer assembly must sum up the two inputs from the speedbrake lever and the control column. With spoilers flush with the upper wing surface, as an aileron moves up, the spoiler on that side will move up; with spoilers full open, the spoiler on the down-aileron side will retract. At any intermediate setting of the speedbrake lever, one spoiler will move up and the other down.

As has been noted in *Traveler* descriptions of the landing gear, the main gear may be extended for additional braking effect. The relative amount of air drag is less than from spoiler action, and the time required is some seconds longer. But, since the main landing gears do not "blow down," and can be extended at any airspeeds up to 375 knots IAS, they add appreciably to braking effect in the middle speed range. The pilot control for MLG extension for use

as an airbrake is located adjacent to the speedbrake lever.

AILERON-SPOILER MIXER

The aileron-spoiler interconnect unit in the 880M is a mechanical mixer assembly located in the hydraulic compartment between the wings. It receives its input from the pilot's control wheels, from the speedbrake control lever, or from an autopilot motor mounted near the mixer. Its operation can best be analyzed by considering first the aileron and speedbrake functions separately, and then the interconnecting action.

Aileron control itself is direct and comparatively simple. Turning the pilots' control wheels actuates pushpull rods and bellcranks (interconnected between the control wheels), and a pair of cables on each side transmits the movement aft to T-cranks. Only the T-crank on the left (pilot's) side is connected to aileron control; the copilot's aileron control is thus exercised via the left-hand pair of cables, through the interconnection between the control columns. Pushpull rods from the left-hand T-crank move vertical levers, which in turn actuate aileron input bellcranks on each side of the assembly. Cables from these bellcranks pass through the wings, via idler cranks where the direction changes; dual pushpull rods move the flight tab horn by means of bellcranks at aileron and tab hinge lines.

The aileron tab control is reversible, so that aerodynamic forces acting on the tab are transmitted back through the mixer to the control wheels. A torsion bar in the mixer adds to pilot feel and acts as a centering spring. To maintain equal surface displacement, the ailerons are interconnected by a pushpull rod linkage.

The pilot's speedbrake handle is part of a quadrant assembly, from which cables run aft to a bellcrank near the mixer. A rod, connecting the bellcrank to the mixer, operates a second closed cable-and-quadrant system. Two quadrants, mounted on a swinging frame, actuate levers that operate the pushpull rods to the spoiler selector valves in the wings. When the swinging frame is stationary, moving the speedbrake control lever rotates the quadrants an equal amount but in opposite directions, causing the selector valve linkages to each wing to move either outboard simultaneously or inboard simultaneously. This moves the spoilers up or down in unison.

The mechanism that makes possible spoiler use for lateral control is the swinging frame. The right-hand pair of cables from the copilot's control wheel runs to a T-crank which is mechanically linked to the swinging frame. Turning of the copilot's control wheel (by the copilot, or by the pilot through the control column interconnection) causes the swinging frame to pivot; the spoiler selector valve linkages to each wing are moved right simultaneously, or left simultaneously.

How the mixer programs spoiler displacement with reference to aileron input, regardless of speedbrake setting, may now be seen. Whatever the angular position of the quadrants that govern speedbrake operation, pivoting of the swinging frame will move the spoiler linkages in the direction of more spoiler displacement on one side and less on the other.

Should an aileron mechanism jam, the spoilers may be operated for lateral control. This is made possible by a spring link in the interconnection between the pilots' control columns. Since the pilot's wheel is mechanically tied to the aileron tabs, jamming might immobilize this wheel. But the copilot, by exerting enough force on his wheel to overcome the interconnecting spring, could operate the spoilers via the right-hand cables that connect his control wheel with the spoiler bellcrank levers in the mixer.

In the same way, the spoiler lateral control system can be overridden by the pilot.

Autopilot input is to the spoiler bellcrank levers. It thus operates the spoilers immediately, but the aileron more remotely, via the cables to the flight compartment and back through the left-hand (pilot's) control cables.

The interworking of the two means of spoiler control requires that there be no motion feedback from the aileron system; i.e., aileron movement must not change speedbrake setting. Also, the speedbrake feel spring must be prevented from retracting the spoilers. Therefore, the speedbrake control is irreversible. In the cable-and-quadrant assembly that operates the selector valve linkages, the driving quadrant incorporates an irreversible mechanism.

FLAP SYSTEM

The 880M flaps are similar to the conventional type in use on propeller-driven aircraft. There is an inboard and outboard flap on each wing. The inboard extends from fuselage to aileron; the outboard extends approximately 15 feet outboard from the aileron. All flaps are double slotted type. Each flap is mounted on tracks by means of carriage roller assemblies. Carriages near the ends of each flap are actuated by screwjacks that control extension and retraction.

Maximum extension is in an arc to approximately 50° downward in the outboard flaps, and 55° in the inboard flaps.

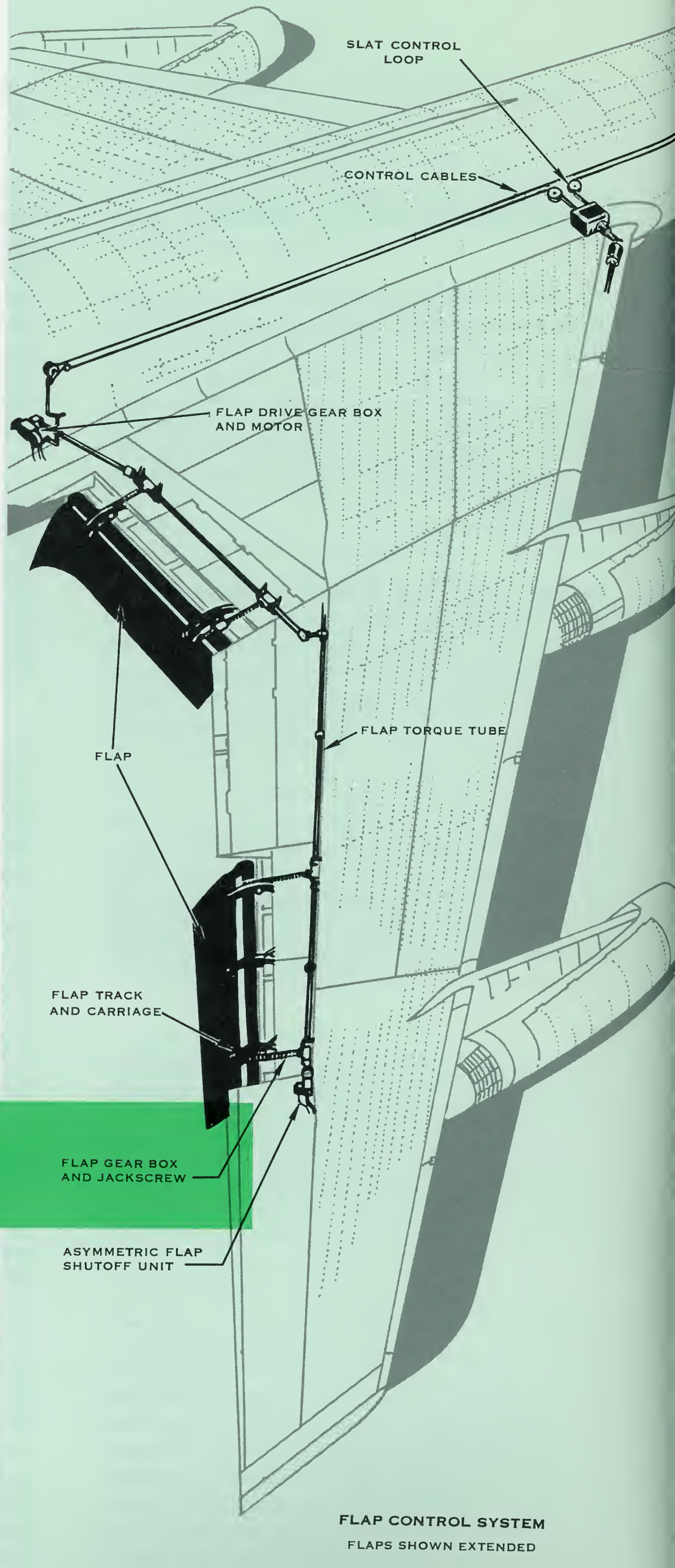
The principal difference between Convair's new jet transport flaps and the "440" flap system is that, instead of being provided with a gearbox in each wing, all "880" flaps are operated from one gearbox, located just below the aileron-spoiler mixer, at the airplane centerline. Two hydraulic motors, one for each hydraulic system, are coupled to the gearbox. Torque rods connect the gearbox with the screwjack mechanisms that extend the flaps.

One advantage of the centerline location of the flap gearbox is that it permits direct manual control of the hydraulic selector valve. The pilot control is a lever, connected by cables to a dual hydraulic control valve. Enough overtravel is permitted in the valve for the pilot to move the lever immediately to

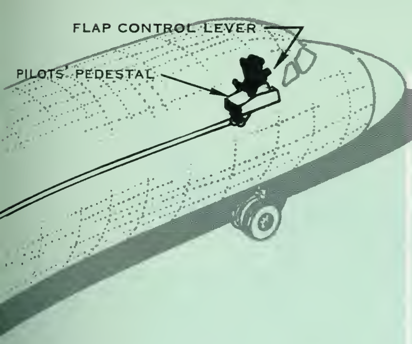
the desired flap position. A follow-up lever on the valve stops flap travel at the selected extension.

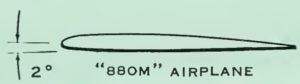
The pilot control lever has detents and markings at 0°, 22°, 33°, 44°, and 55°.

A dual flap indicator on the instrument panel shows position of the outboard flap in each wing. Permissible airspeeds for flap-extended positions are listed on a placard. The warning horn for takeoff is connected between flaps, MLG struts, and the throt-

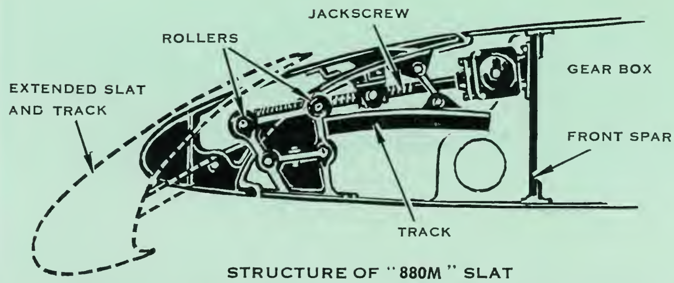


FLAP CONTROL SYSTEM
FLAPS SHOWN EXTENDED

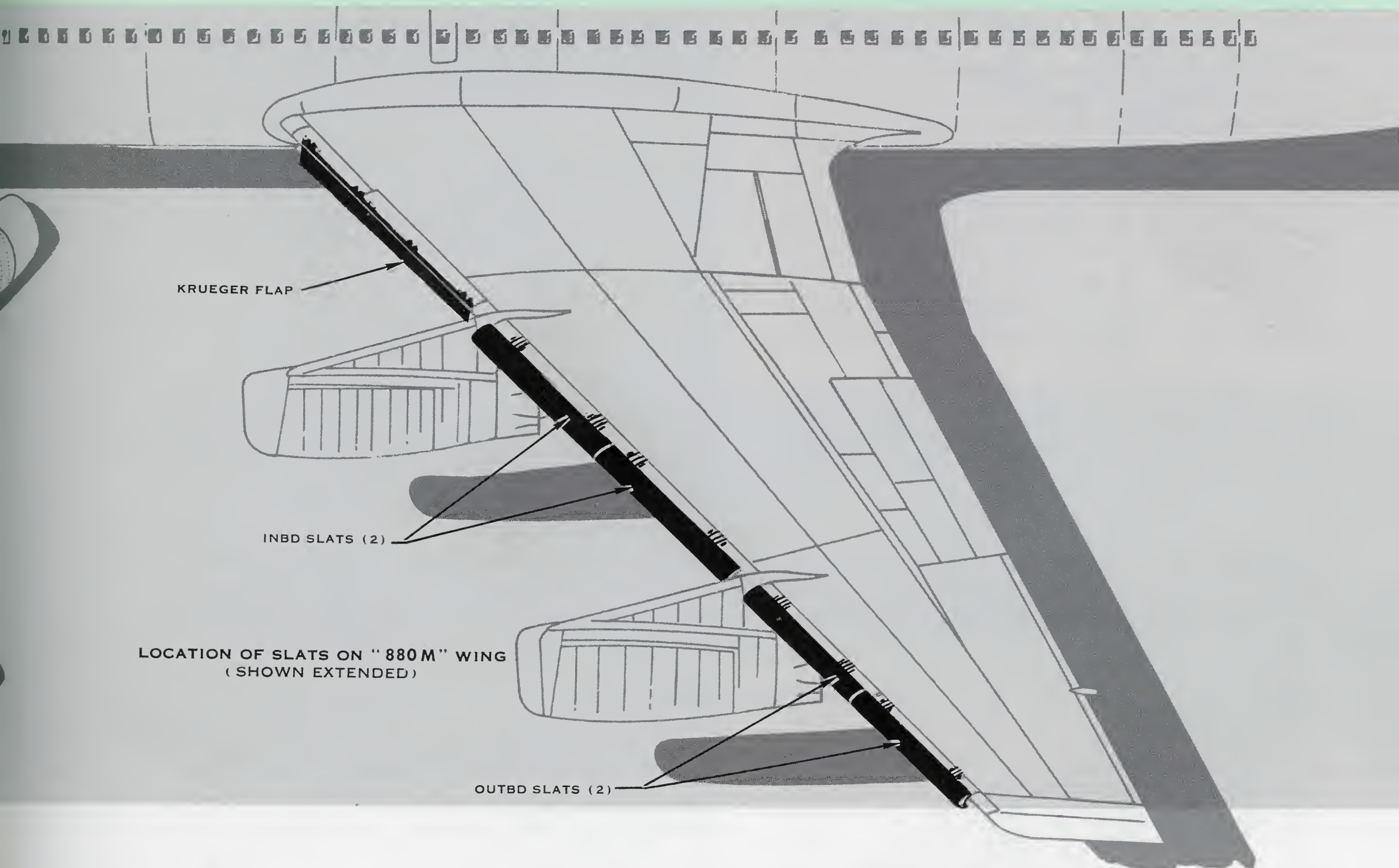




WING ANGLE OF INCIDENCE



STRUCTURE OF "880M" SLAT



LOCATION OF SLATS ON "880M" WING (SHOWN EXTENDED)

tles, and sounds if a pilot should attempt to take off with the flaps in any position other than the takeoff setting.

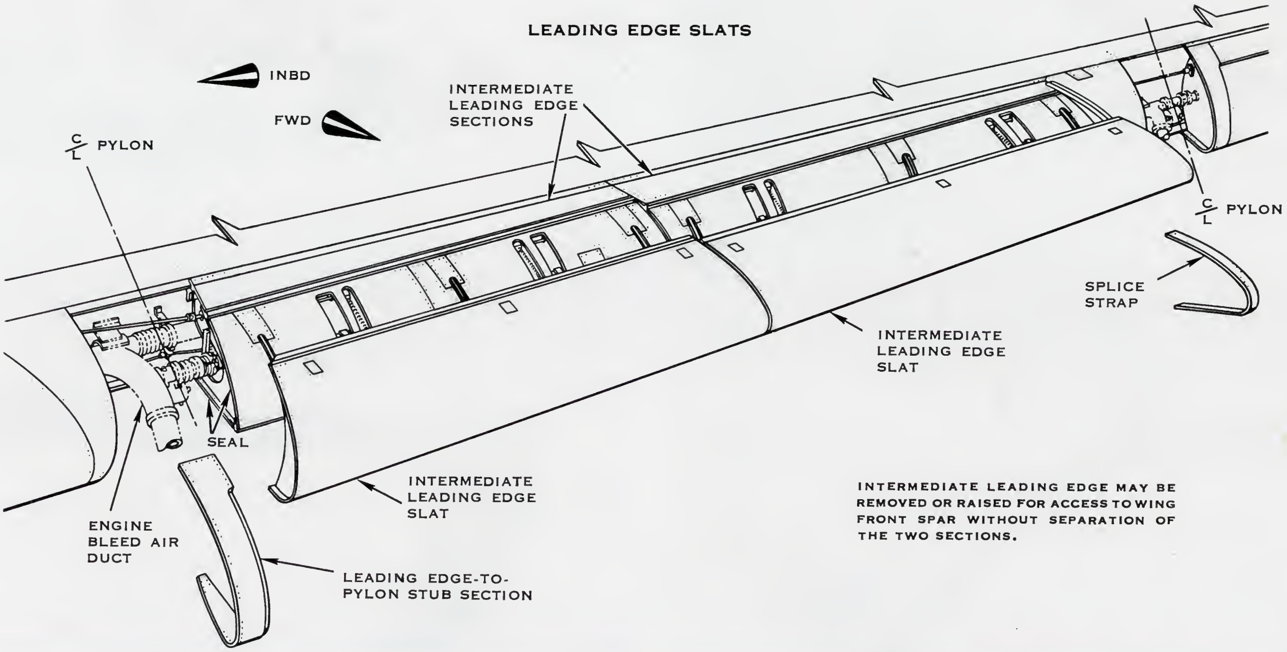
SLAT AND KRUEGER FLAP SYSTEMS

Two extensible leading-edge devices increase wing angle of attack for useful lift, thereby increasing effective lift at low takeoff and landing speeds.

Inboard of the inboard engines are three-section Krueger-type leading edge flaps. They are essentially flat plates (although actually contoured to form part of the wing under surface when retracted) and are hinged on the front so as to swing down and forward in a 100° arc. They block a certain amount of airflow under the wing and direct it across the upper surface.

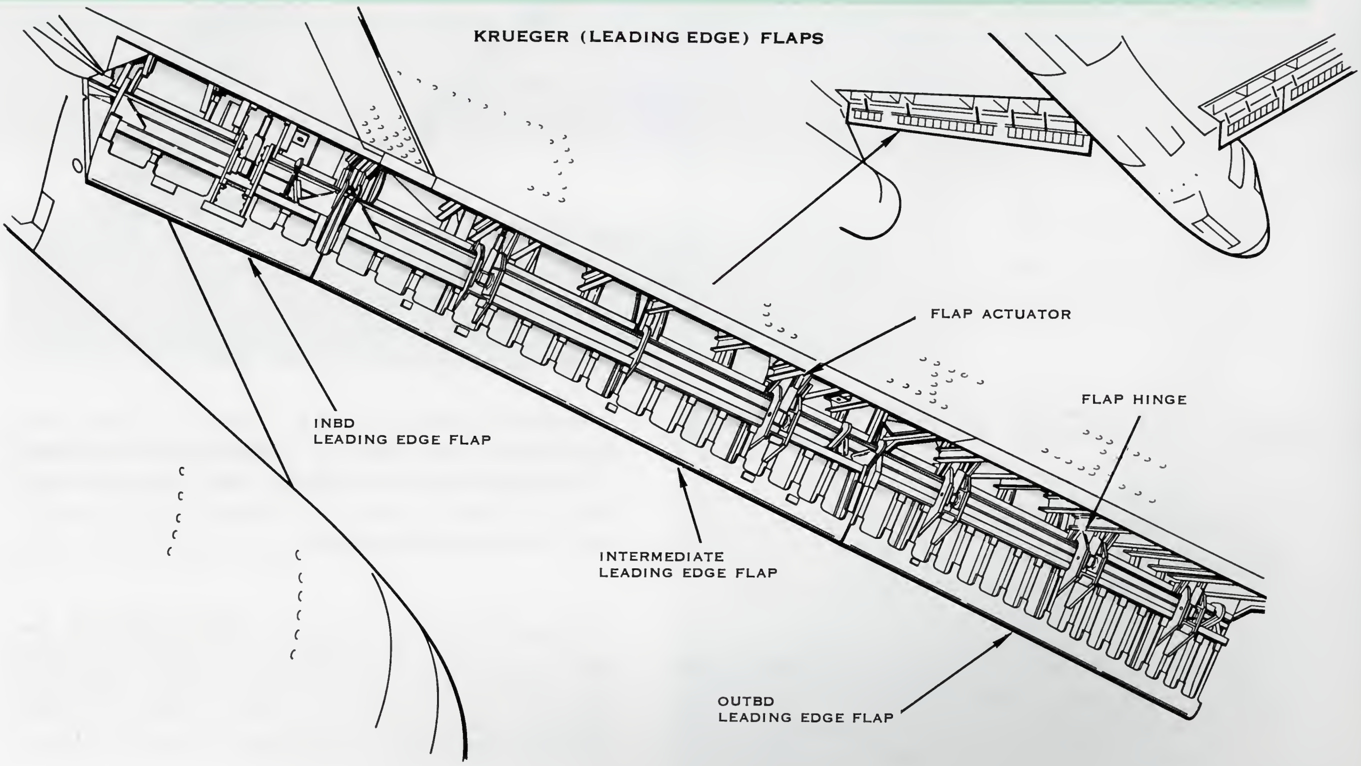
Outboard of the engines are slats, two between the engines and two outboard. These are airfoil-shaped sections, forming the leading edge when retracted and extending on curved tracks down and forward in a 15° rotational movement.

Krueger flaps and slats are all extended by one drive assembly, powered by two hydraulic motors, one operating from each hydraulic system. A gearbox drives one torque tube for the flaps and another for the slats. The torque tubes drive a total of 28 screw-



jack actuators, six in each Krueger flap and two each in the slats. Control is through a dual hydraulic valve.

Leading edge flaps and slats are extended automatically with the trailing edge flaps. A loop in one of the flap control cables operates the hydraulic control valve for the leading edge devices. By the time the cockpit flap control lever has been moved halfway to takeoff position (the 22° detent), the valve has opened to extend Krueger flaps and slats. The leading edge devices have no intermediate setting; they are either retracted or fully extended. The actuation is instantly reversible, however, whenever the control lever is moved back to flap-retracted position.



880 EMPENNAGE FLIGHT CONTROLS

The flight control systems on the Convair 880 are designed for the wide range in speed and altitude of Convair's new jet transport. In external appearance, and in most operating characteristics, these controls are similar to those of any high-speed transport airplane; but there are some basic differences.

The primary flight control system consists of elevator, rudder, and aileron controls. Main surfaces of these controls are operated by flight tabs, controlled manually by the pilot through bellcrank and cable linkages. Flight tab movement is opposite to control deflection. Right-hand deflection of the rudder tab, for example, moves the rudder to the left, giving the pilot a large mechanical advantage to move the main surfaces. This manual operation, besides being simple and reliable, has the advantage of providing reversible controls; that is, the air pressures acting on the flight tabs are transmitted back to the pilot's controls, so that he has direct feel of the aerodynamic resistance to deflection.

The secondary flight controls are the trim systems, the wing flaps, and the spoiler-speedbrakes. These are all actuated hydraulically or by manually-operated screw-jack mechanisms, and so are irreversible controls. Spoiler-speedbrakes, innovations in transport aircraft, are movable flaps on the top wing surface that can be deflected upwards to break airflow across the wing. Since they operate in conjunction with the aileron, to this extent spoilers are part of the primary aileron control system. They can also be used as secondary controls to slow the airplane in flight.

Described are the empennage controls — vertical and horizontal stabilizers, rudder and elevator systems, and the directional and longitudinal trim systems. Aileron, spoiler-speedbrake, and flap systems are discussed on pages 43 through 50.

Following are general characteristics and some of the considerations that governed the design of the "880" flight control systems.

Special emphasis has been placed on making control linkages simple and as friction-free as possible. There are no pulleys in main control cable lines, for example, and, at points where the cables must change direction, they ride on idler cranks. Centering springs, to bring the controls back to trim neutral when the cockpit controls are released, are preloaded to provide enough force to overcome all friction in the linkages.

Longitudinal control is designed to 2½ G's at 120 pounds maximum force applied by the pilot; that is, a 120-pound pull on the control column will cause approximately a 2½-G pull-up. Design limit forces on rudder and elevator controls are 300 pounds, applied by either pilot, or 225 pounds by each pilot simultaneously, applied either in conjunction or in opposition. Control cable tension is set to be at least half the differential load on the cable system resulting from maximum operation load at any flight condition. Cable tension regulators are not required.

Pilot and copilot controls are interconnected, with stops on the flight compartment controls and at the rudder and elevators. Self-contained hydraulic damper mechanisms, not connected to the airplane hydraulic system, serve as ground gust protection. At streamline position, these dampers have no inhibiting effect on control movement. Damping is progressively greater as the surface is displaced and, at 2° from the limits of surface movement, the dampers serve as snubbers.

Rudder, elevators, and flight tabs are mass balanced with tungsten counterweights for flutter prevention. The main surfaces are sufficiently aerodynamically balanced to reduce hinge moments to acceptable limits. For an additional margin of safety, all actuating rod linkages for flight tab control surfaces are duplicated for protection against screw thread or nut failure.

Where necessary, metal laminates and honeycomb construction are utilized, both for sound damping and for strength.

The high speed capability of the "880," and design requirements for jet aircraft, made necessary two departures from the control systems that have been standard on transports such as the Convair-Liners: 1) provisions for extra "feel" combined with limitation of control deflection at high speeds, and 2) a major redesign of the elevator trim system, involving trim movement of the entire stabilizer-elevator assembly.

The structure of the stabilizers and control surfaces, and the operation of the rudder, elevator, and trim systems, are described in separate detail following.

EMPENNAGE STRUCTURE

Both horizontal and vertical stabilizers, like the wing, have a 35° sweepback at the 30 percent chord line. The horizontal stabilizer has 7° dihedral. The stabilizers are of spar box construction, utilizing extruded rails, stiffeners, and webs. The vertical stabilizer tip is 36 feet from the ground, more than 20 feet above the fuselage. The horizontal stabilizer is approximately 39 feet in span. It is somewhat aft of the fin, so that the horizontal stabilizer tips are 5 feet aft of the fin tip.

The vertical stabilizer is replaceable as a unit. It attaches to the fuselage at six points, three on each side of the centerline. There are three main spars and an auxiliary, or leading edge, spar which is the point of attachment for the removable leading edge assembly. The main spars have rails of extruded 7075T6 tees with aluminum webs and stiffeners. The auxiliary spar has extruded tee rails of 2024T4, with cross-bracing and no web. The six forged fuselage attach fittings are at the lower ends of the three main spars, and attach to fittings at fuselage frames.

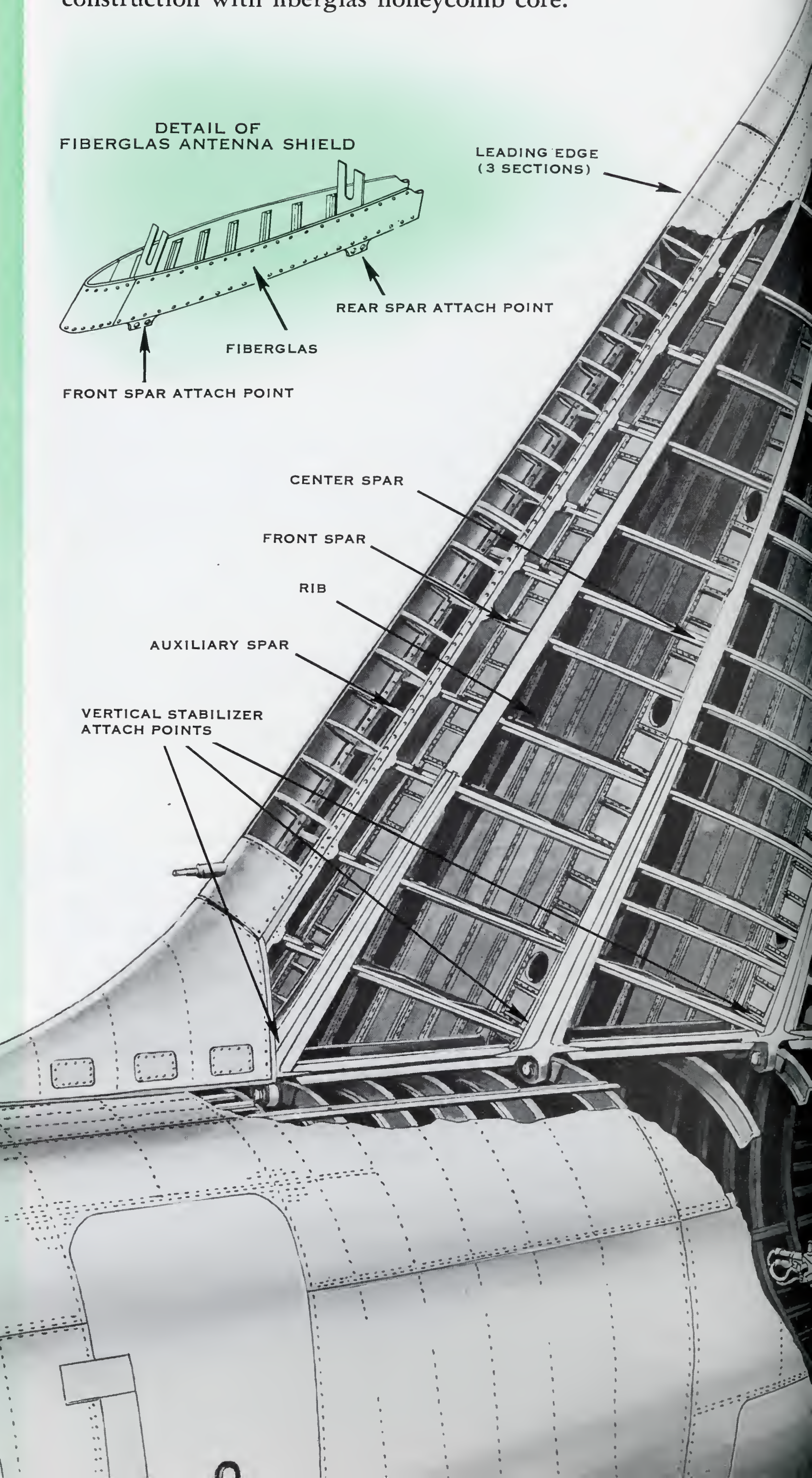
The tip assembly is a high-frequency broadcast and receiving antenna. It is shielded from the spar box by a 10-inch-wide structure of fiberglas, attached to four fittings at the upper ends of spars 1 and 3. The VHF navigational antenna, and two HF couplers, are in the upper portion of the spar box.

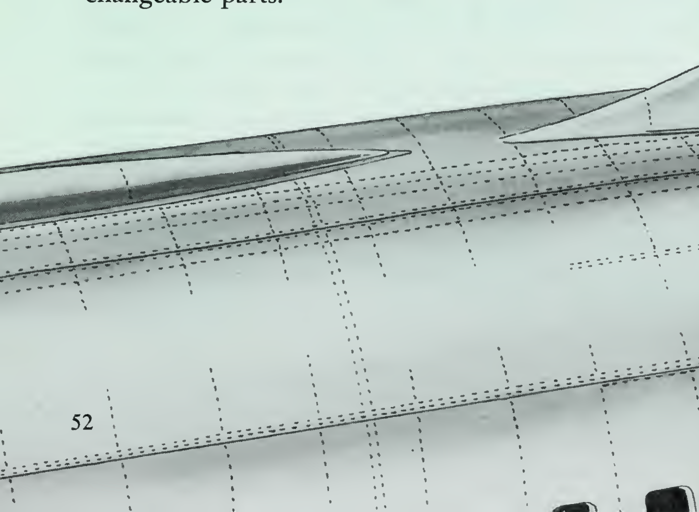
The leading edge assembly is in three sections, attached with screws to the auxiliary spar rails, and sealed between sections with silicone rubber seals. The assemblies are built-up sections consisting of 2024T4 formed ribs covered with skins laminated for anti-icing. An internal skin of 2024T4 is riveted to the ribs. Bonded to the outside of this skin is a plastic layer approximately .037 inch thick, in which are embedded electrically-heated wires. The external surface is stainless steel, providing a smooth leading edge with no exposed rivets.

Antenna tip, fiberglas insulating shield, and the leading edge assemblies, are removable and interchangeable parts.

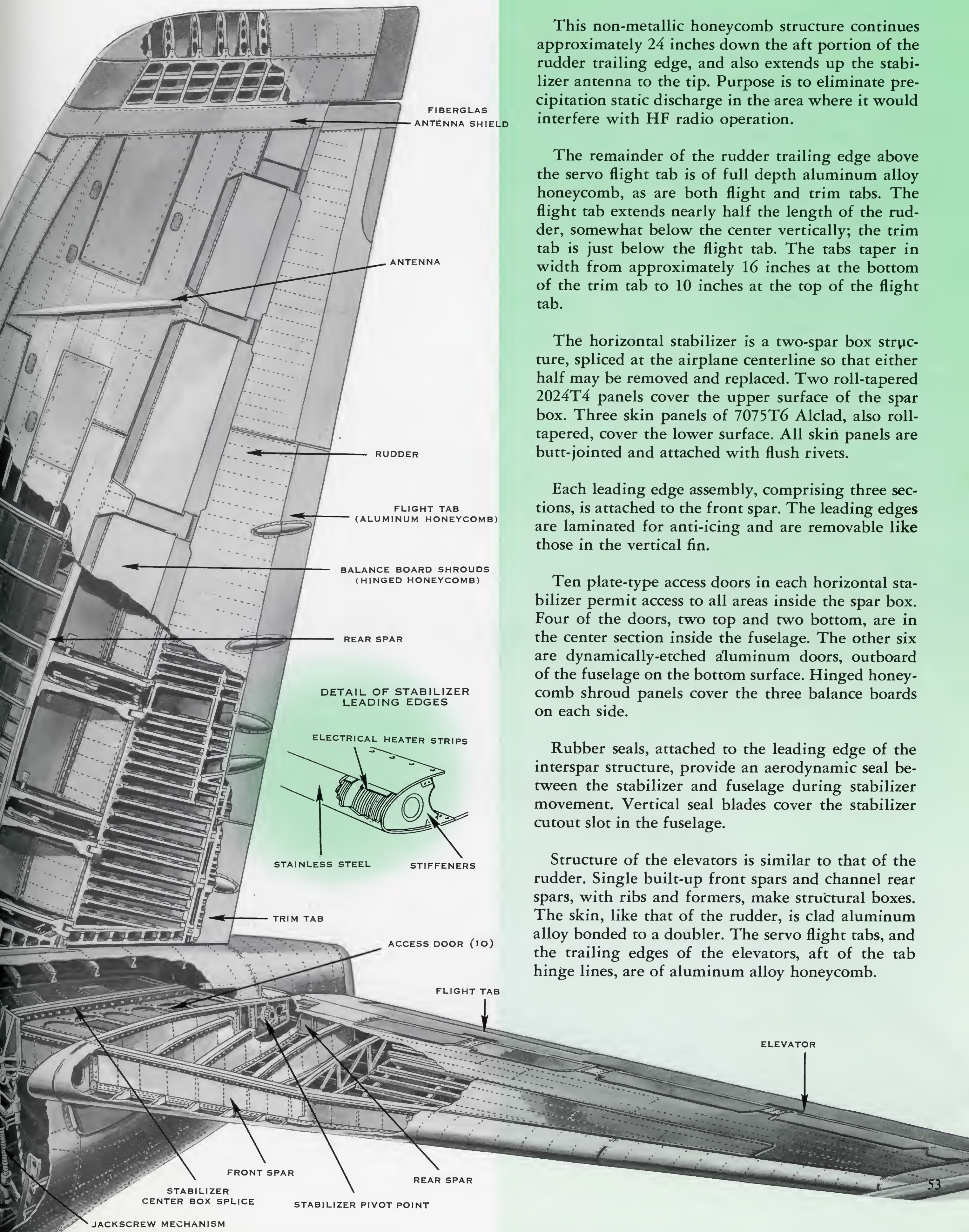
Three large plate access doors are provided on the spar box left side for interspar access. In the trailing edge, three hinged aluminum honeycomb shroud panels cover the rudder balance boards.

The rudder has a single main spar, near the leading edge, and two auxiliary spars. These, with horizontal ribs and formers, comprise a structural box. Except for the upper tip, the skin is in effect a double laminate. A reinforcing doubler of aluminum alloy is bonded to Alclad skin over much of the skin area, with cutouts in the doubler between the formers. The upper tip, because it extends up into the interference zone of the fin tip antenna, is fiberglas construction with fiberglas honeycomb core.





Cutaway View Showing "Fail-Safe" Structure of Empennage



This non-metallic honeycomb structure continues approximately 24 inches down the aft portion of the rudder trailing edge, and also extends up the stabilizer antenna to the tip. Purpose is to eliminate precipitation static discharge in the area where it would interfere with HF radio operation.

The remainder of the rudder trailing edge above the servo flight tab is of full depth aluminum alloy honeycomb, as are both flight and trim tabs. The flight tab extends nearly half the length of the rudder, somewhat below the center vertically; the trim tab is just below the flight tab. The tabs taper in width from approximately 16 inches at the bottom of the trim tab to 10 inches at the top of the flight tab.

The horizontal stabilizer is a two-spar box structure, spliced at the airplane centerline so that either half may be removed and replaced. Two roll-tapered 2024T4 panels cover the upper surface of the spar box. Three skin panels of 7075T6 Alclad, also roll-tapered, cover the lower surface. All skin panels are butt-jointed and attached with flush rivets.

Each leading edge assembly, comprising three sections, is attached to the front spar. The leading edges are laminated for anti-icing and are removable like those in the vertical fin.

Ten plate-type access doors in each horizontal stabilizer permit access to all areas inside the spar box. Four of the doors, two top and two bottom, are in the center section inside the fuselage. The other six are dynamically-etched aluminum doors, outboard of the fuselage on the bottom surface. Hinged honeycomb shroud panels cover the three balance boards on each side.

Rubber seals, attached to the leading edge of the interspar structure, provide an aerodynamic seal between the stabilizer and fuselage during stabilizer movement. Vertical seal blades cover the stabilizer cutout slot in the fuselage.

Structure of the elevators is similar to that of the rudder. Single built-up front spars and channel rear spars, with ribs and formers, make structural boxes. The skin, like that of the rudder, is clad aluminum alloy bonded to a doubler. The servo flight tabs, and the trailing edges of the elevators, aft of the tab hinge lines, are of aluminum alloy honeycomb.

The rudder is controlled by movement of the pilot's or copilot's pedals. Forward movement of a pedal pulls a bellcrank aft, rotating an interconnect rod between the pilot's and copilot's pedals, and moving the other pair of pedals in unison. Another arm of the torque tube actuates the flight tab actuating cables, one on each side of the cockpit.

These cables pass aft through pressure seals, via idler cranks, to an idler-quadrant assembly. The quadrant of this assembly is part of the autopilot control system on the 880M. From the idler, through a linkage that includes a pedal force limiter, cable movement is transmitted aft through dual rods to a rudder hinge bellcrank, from which another pair of dual rods runs to the flight tab horn. Following the force limiter, a mixer unit interchanges pedal force to the tab system or to a hydraulic rudder boost system, depending on system parameters.

The pedal force limiter, a compression spring cartridge, is preloaded to an equivalent pedal force of 180 pounds. The controls are so rigged that at 225 knots IAS, 180 pounds pressure will give full deflection up to boost system stops. When pedal pressure exceeds this, the spring compresses at a rate of approximately 45 pounds per inch as measured at the pedals.

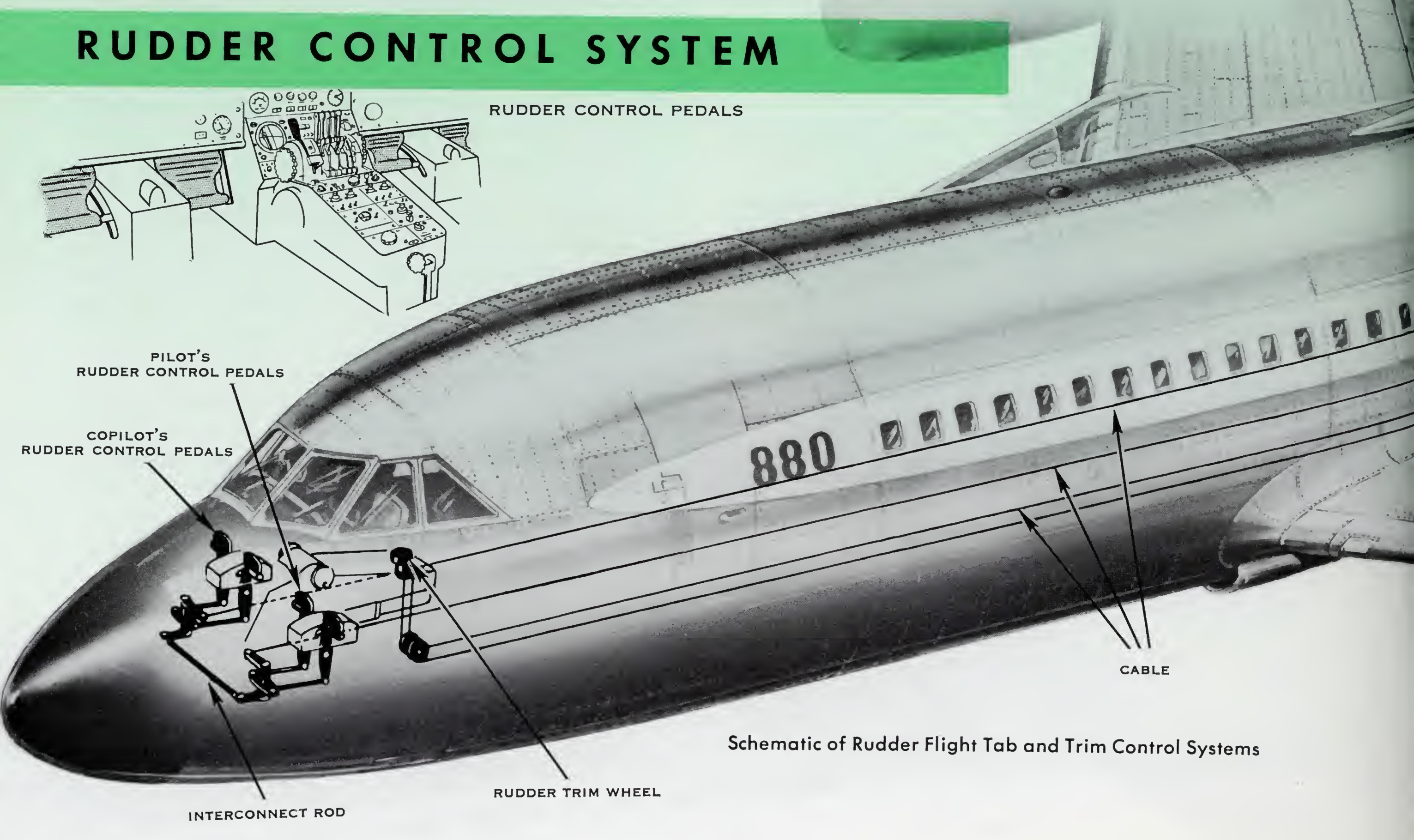
Just aft of the overload spring, "Q" pressure is applied as a force in the linkage, via a rod actuated by a feel cylinder diaphragm. The "Q" pressure is admitted at the base of the fin through a ¾-inch inlet, electrically heated to prevent icing. "Q" pressure is conducted to one side of the feel cylinder diaphragm; the other side is vented to ambient through flush openings on each side of the fin. This "Q" force function limits deflection at high speeds. These are safety measures, added because of the moderate flight tab forces felt at the rudder pedals.

At the high speeds of which the "880" is capable, excessive pedal pressure could conceivably cause an overstress of the fin, due to excessive rudder deflection. This is prevented through an interaction of "Q" force with overload spring compression in the pedal force limiter. No matter how hard the pilot may push on the pedal, deflection of the tab and rudder will be held within safe limits.

The bellcrank on the rudder hinge is connected to a spring centering mechanism. Preload on this centering spring is 7 pounds at the pedal. Static friction at the pedal, by design requirement, must not exceed 5 pounds. Thus, the centering spring provides enough force to return the flight tab to streamline with respect to the rudder, whenever the cockpit controls are released, and the rudder will blow back into streamline.

Maximum deflection of the flight tab is 21°; maximum rudder deflection is 19°. Rudder pedal travel, due to maximum flight tab travel, is 1⅜ inches for-

RUDDER CONTROL SYSTEM

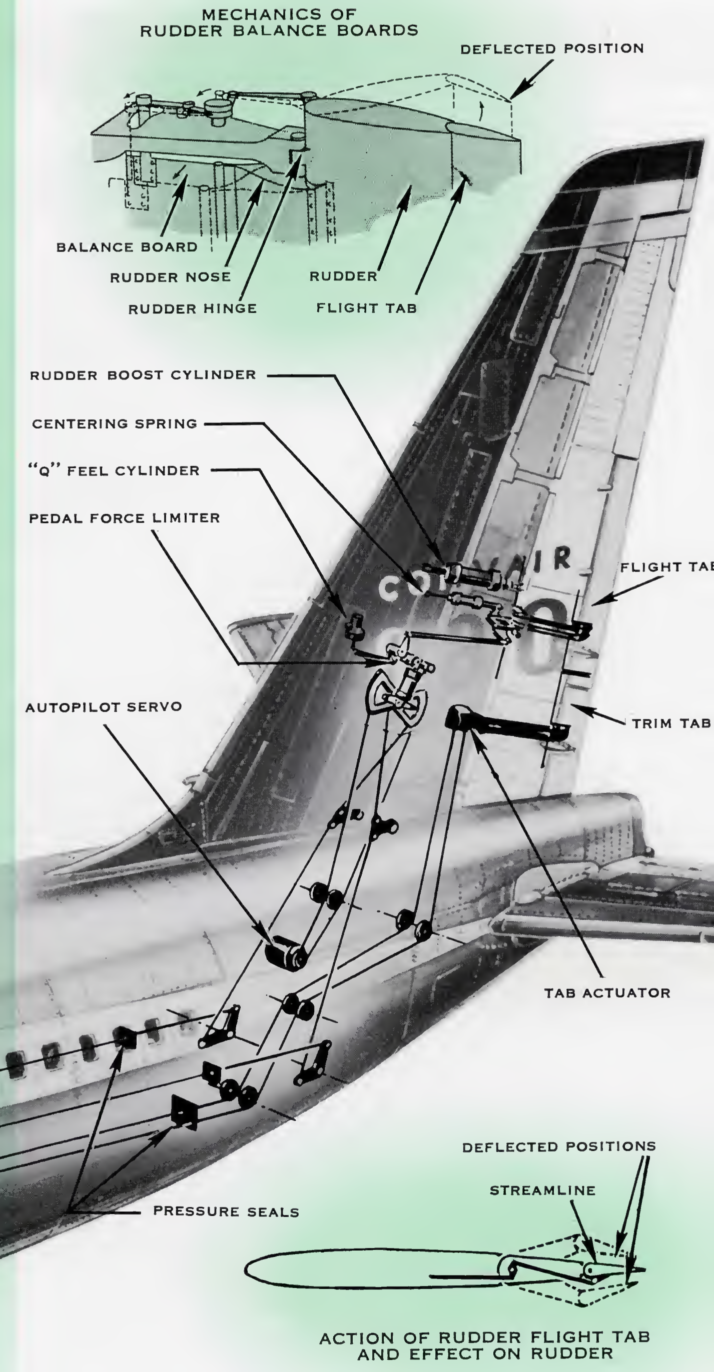


Schematic of Rudder Flight Tab and Trim Control Systems

ward and aft from neutral; pedal travel, due to combined rudder and flight tab travel, is 2⅝ inches forward and aft from neutral. The pedals are adjustable within a 7-inch range. Stops are provided on pedals and trim cables, and on the rudder and flight tab, to limit travels to the amounts set.

To insure sufficient rudder deflection when in flight tab (manual) mode, a series of three balance boards are attached to the rudder along the vertical leading edge. These boards move in compartments in the trailing edge of the vertical stabilizer. The compartments are sealed except at the aft end, where there is a ¾-inch gap between rudder and stabilizer skins. Deflection of the rudder to the left will cause a buildup of pressure on the left side at the rudder hinge line, with a resultant positive pressure on the left surface of the balance boards, and with a simultaneous negative pressure on the right side from venturi effect.

The boards are attached to the rudder by a parallelogram type of mechanism, so that the differential of air pressures on each side of the boards exerts a boost force to help deflect the rudder. The parallelogram attachment has been found more effective than having the board affixed directly to the rudder. Wind tunnel tests on the "880" have shown that at 10° rudder deflection, a fifth of the operating hinge moment is provided by the balance boards; at full deflection, the boards provide nearly half the hinge moment.



ACTION OF RUDDER FLIGHT TAB AND EFFECT ON RUDDER

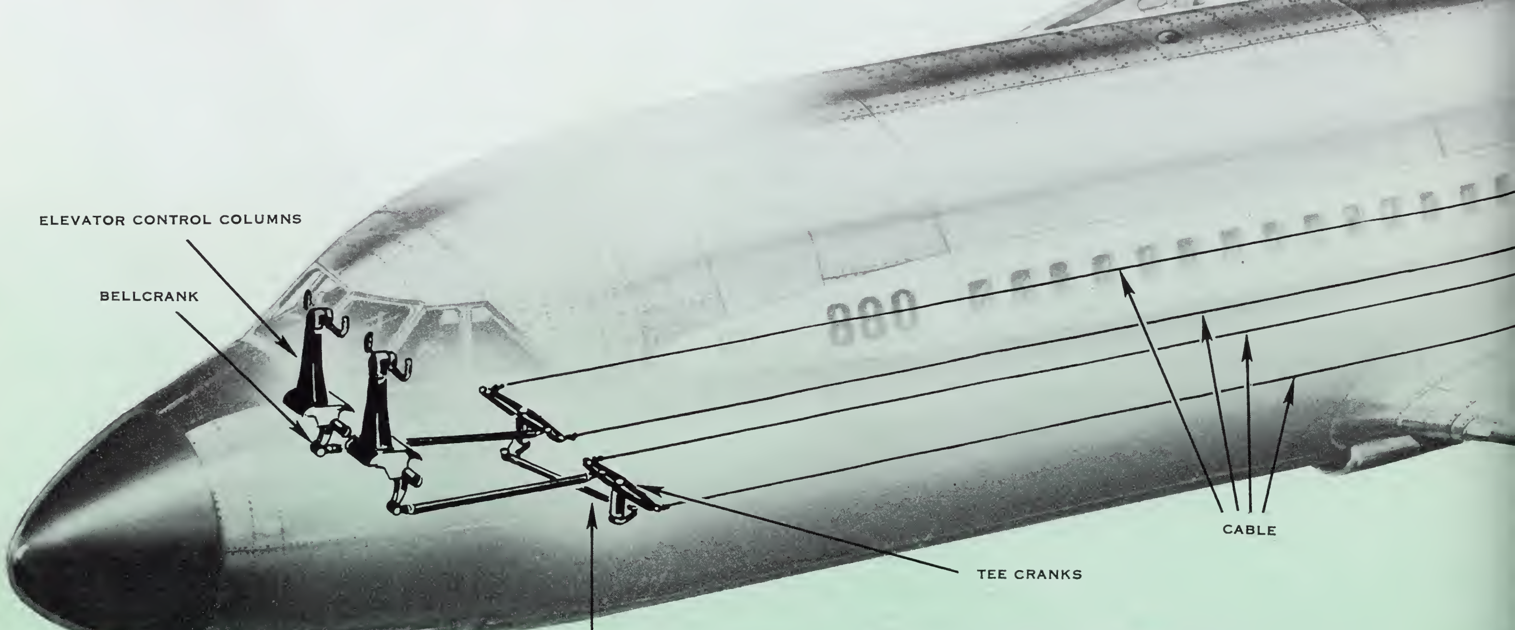
The boards themselves are a sandwich type of construction, two aluminum alloy sheets separated by a ¼-inch-thick spacer.

In addition to the pilot input during manual flight, the rudder flight control tab receives inputs from the autopilot servo motor, which is controlled by the yaw damper-turn coordinator. Yaw rate is sensed by the primary autopilot control (rate gyros in the Bendix PB-20 autopilot, accelerometers in the Sperry SP-30 autopilot). The signal from the sensors directs a rudder movement proportioned to the yaw disturbance. Steady-state turn coordination will hold sideslip and lateral acceleration to less than 0.05 G.

The yaw damper-turn coordinator and the autopilot are controlled by switches mounted on the autopilot control panel.

ELEVATOR CONTROL SYSTEM

Right- and left-hand elevators are completely separate, the only interconnection between them being the push-pull linkage that controls the flight tabs. The elevator flight tabs are controlled by push-pull movement of the control columns. This movement is transmitted to tee cranks, which are inter-

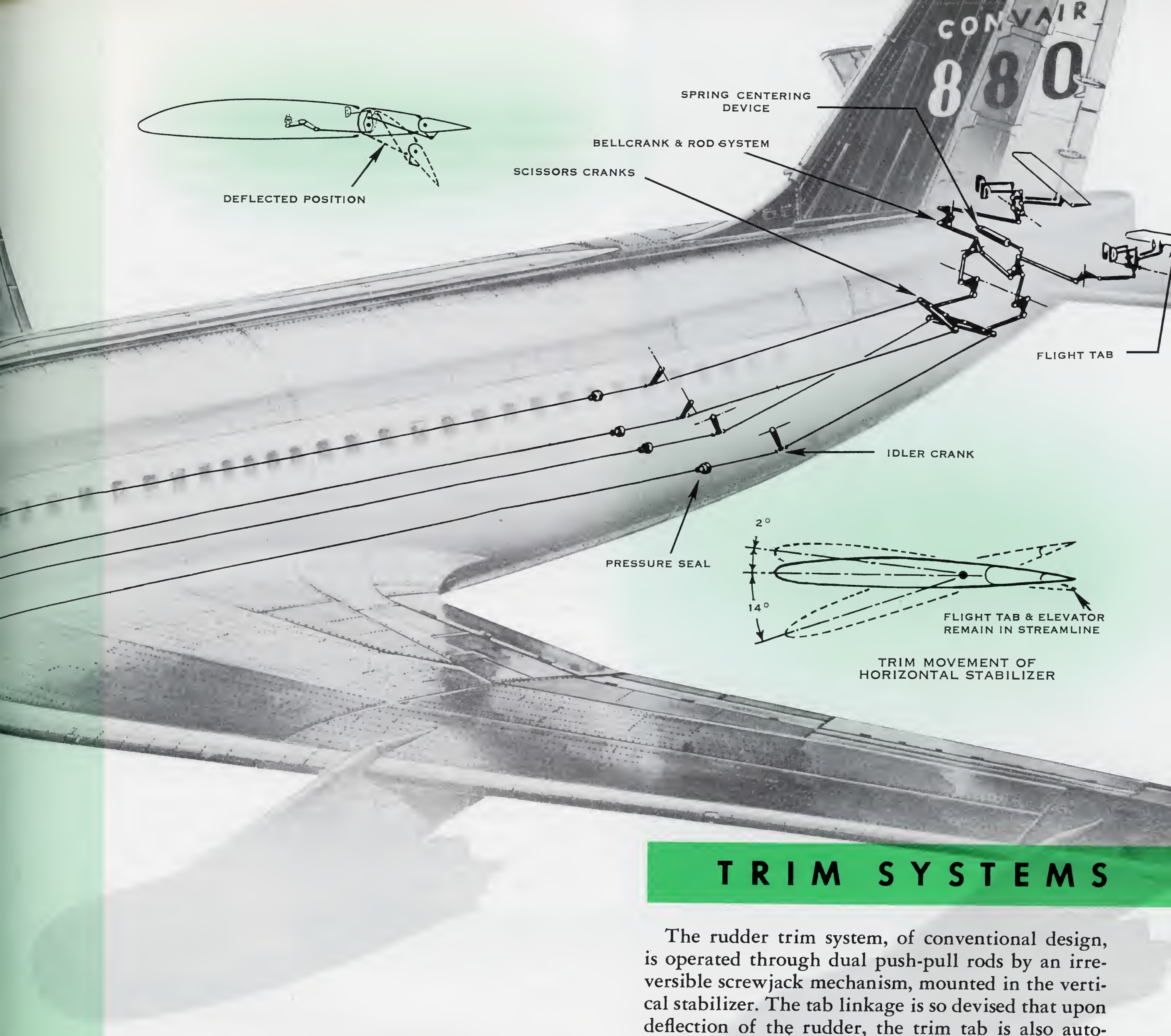


Elevator and Flight Tab Control Systems

connected so that the two control columns will move in unison. From each tee crank, two cables run aft through cabin pressure seals to a scissors crank assembly. Push-pull rods from the scissors cranks, through bellcranks, operate levers that move the linkage between the two elevators. This linkage moves the tabs through dual push-pull rods and bellcranks.

Autopilot input is at one of the bellcranks between the scissors cranks and the interconnecting linkage between the elevator flight tabs.

Maximum deflection angles, for both the elevators and the tabs, are 26° elevator trailing edge up (flight tab down) and 13° elevator trailing edge down (flight tab up). Control column travel is 4 inches aft of neutral and 2 inches forward to obtain maximum tab deflection, and 8 inches aft and 4 inches forward for combined elevator and flight tab travel. Stops on the control column are set at 5 inches forward of neutral, and at a point that limits aft travel to that required to obtain maximum up elevator with 120 pounds force on the control column. Stops are provided on the flight tab linkage. Elevator stops are



designed to withstand maximum gust loads in excess of those absorbed by the gust dampers.

For speed braking, the "880" has, in addition to the spoiler-speedbrakes on the wings, provisions for extending the main landing gears. This has an effect of increasing the lift forward of the center of gravity, causing a definite nose-up tendency. Pilots have noted this pitch moment to a lesser extent in propeller transports when landing gears are extended. In the "880," the pitch is more pronounced.

TRIM SYSTEMS

The rudder trim system, of conventional design, is operated through dual push-pull rods by an irreversible screwjack mechanism, mounted in the vertical stabilizer. The tab linkage is so devised that upon deflection of the rudder, the trim tab is also automatically deflected to provide aerodynamic boost to rudder movement.

The trim actuating mechanism is controlled by cables that run through pulleys to the flight compartment. A single 3-inch rudder trim wheel, and a trim indicater, are mounted on the aft portion of the pedestal. Turning the wheel operates a gearbox, the output shaft of which operates the cables. Movement of the wheel also positions the indicator. Rudder trim wheel travel for manual trim (16° left or right) is five turns left or right from neutral.

The all-movable horizontal stabilizer is the feature of the "880" empennage that is the largest departure from conventional transport construction. The stabilizer is hinged aft of the rear spar, and moves up and down as a unit in a "slot" in the fuselage to provide longitudinal trim.

The reason for this design is the comparatively small tail of the "880." Tail area of the "880," relative to wing area, is approximately half that of the Convair 440 Metropolitan, for example. The smaller tail, with less drag, is possible in jet-powered aircraft because the airplane aerodynamic balance and the effectiveness of the controls are less affected by power setting; there is no propwash over the tail surfaces.

However, the "880" speed range and allowable center-of-gravity shift require a longitudinal trimming moment comparable to that of the "440." At "880" cruise speed, trimming by elevator tabs would result in an undesirable increase in drag. Moving the entire stabilizer provides the large trim moments necessary at takeoff and landing, and the design is aerodynamically clean at cruise.

Trim range of the stabilizer is 14° trailing edge up to streamline. The stabilizer pivots on spindles mounted on the fuselage, one on each side. It rotates on roller bearings, secured to the spindles by split-tapered bushings and nuts.

The leading edge of the stabilizer is moved by a screwjack mechanism. Normally, the screwjack is operated by a hydraulically-powered nut mounted on a universal pivot on the stabilizer front spar; in emergency, it is operated by mechanical rotation of the screw, either by an electric motor or manually.

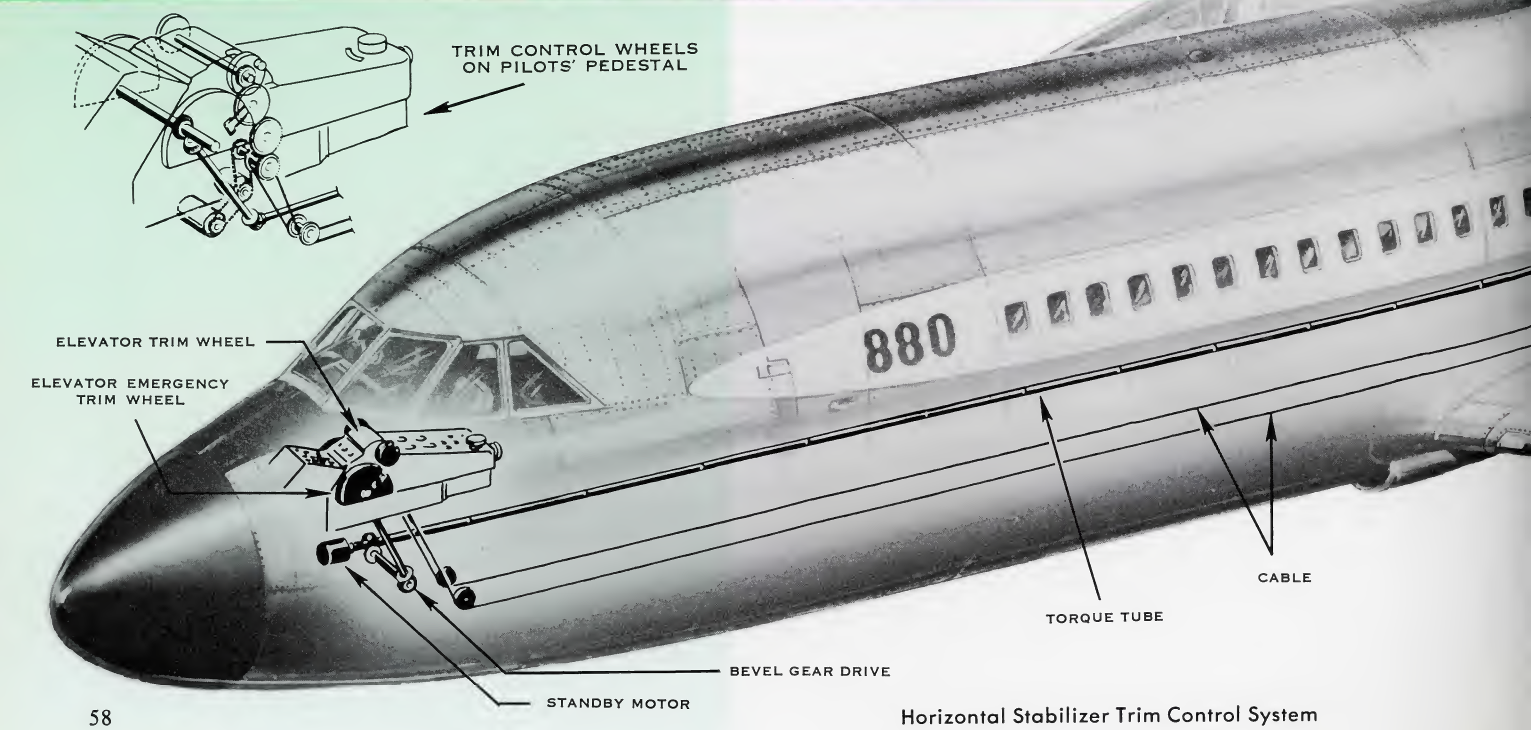
The screw has Acme-type threads, both for extra reliability over the ball-nut installations sometimes used for such purposes, and for assurance that the action will be irreversible. A hydraulic motor drives the traveling nut through a worm gear. The worm drive is also irreversible, to insure that the nut will not turn during emergency operation of the screw. The jack screw, at its lower end, is attached to aircraft structure through universal joint pivots. The screw contains a separate inner member to guard against possible screw failure. The universal joints at the base of the screw and at the nut attachment on the stabilizer are provided with surrounding sockets to insure against universal joint failure.

Hydraulic power from the primary hydraulic system operates the motor, controlled by a selector valve and follow-up screw. The follow-up screw has dual members, to guard against loss of follow-up due to structural failure. This screw is a shaft splined in a helical pattern; rotation of the screw, by cables from the pilots' controls, opens the selector valve ports. As the hydraulic nut moves up and down the jack screw, the selector valves moves with it, and a splined bushing rotated by the splines on the follow-up screw closes the valve ports at the setting selected by the pilot.

The pilot controls for normal trim operation are a pair of 5¾-inch-diameter wheels located on the forward right and left sides of the pedestal. The two wheels are on a common shaft, which is geared to a cable drum. Autopilot and normal electrical trim input are at this point, from servo motors that turn the cable drum.

The cables pass through cabin pressure seals and pulleys to a second drum at the base of the follow-up screw. Control wheel travel to obtain full stabilizer travel (14°) is 12 turns.

STABILIZER TRIM SYSTEM



Horizontal Stabilizer Trim Control System

Below the normal trim control wheel is a crank with a 5-inch throw for emergency trim. The crankshaft is geared directly to a torque shaft that passes aft through pressure seals and universal joints to a bevel gear that rotates the jack screw.

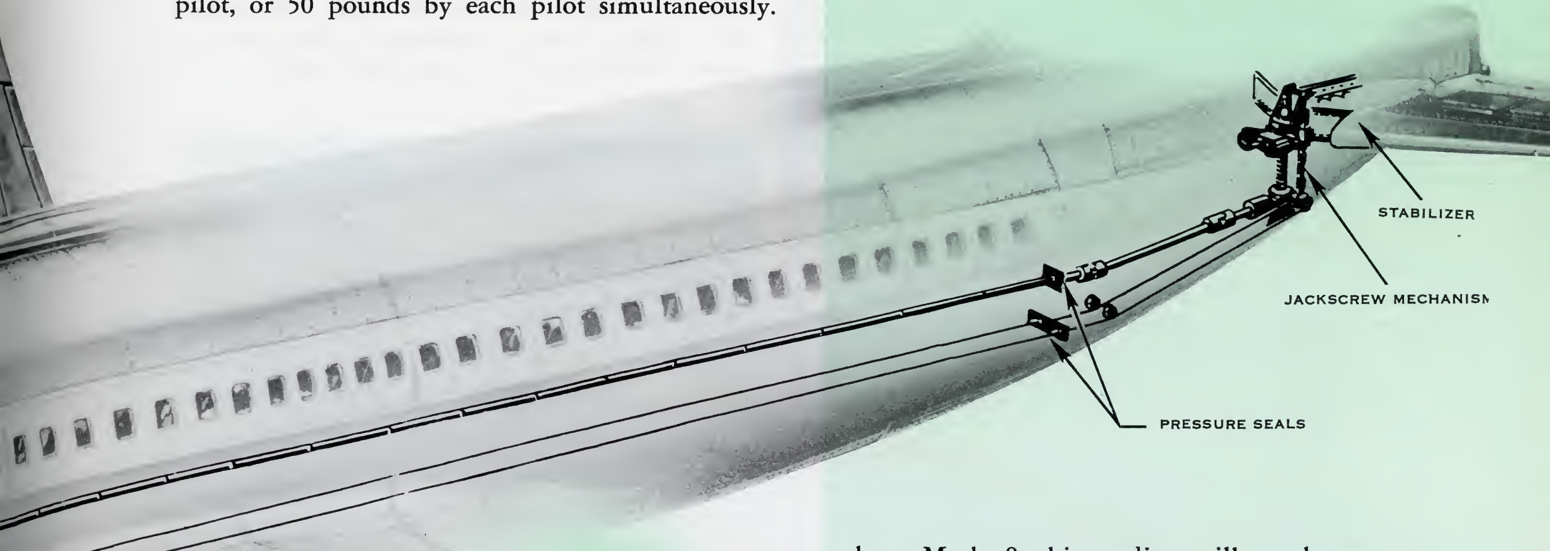
It requires 20 turns of the crank to obtain a degree of stabilizer travel. Therefore, to make emergency trim comparable to normal trim in speed of operation, a 200-volt, 3-phase, reversible a-c motor is installed to operate directly on the fore-and-aft torque shaft. This motor operates through a clutch, so that it can be overridden by manual operation of the crank by the pilot.

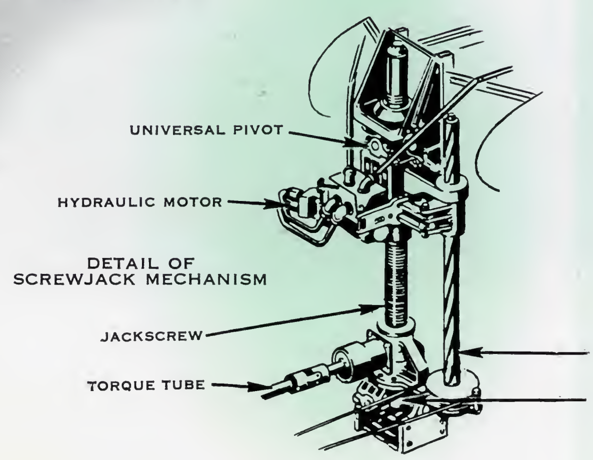
At the base of the jack screw is a device to make the action of the jack screw irreversible, so that the screw will not rotate during normal operation of the hydraulic nut. Accessible to the pilot only is a means to lock the stabilizer emergency trim control cranks in rigged position when operation of the cranks is not required. Operating the crank automatically releases the locking mechanism.

Design limit of the trim crank is approximately 100 pounds applied by one pilot, or 75 pounds applied by both simultaneously, either in conjunction or in opposition. Design limit of the normal trim wheel is approximately 65 pounds applied by either pilot, or 50 pounds by each pilot simultaneously. Stops that will withstand the normal trim wheel force are provided on the control cables at the points where trim deflection limits are reached. Torque type stops are also provided at the screwjack assembly. Breakout force of the normal trim wheel is 2 pounds maximum.

At the "880" top cruising speeds, the "tuck-under" tendency, which is a standard aerodynamic characteristic of transsonic flight, is encountered. The "880" incorporates an automatic compensating feature to relieve the pilot of the trim changes necessary at high speeds. At Mach .8, a Mach-number sensing device operates a small electric motor to give a stabilizer trailing-edge-up trim change that varies with Mach number. The motor is mounted at the base of the follow-up shaft, in such a manner that its input is separate from that given by the cables from the pilot controls. Maximum deflection by this motor is 1.6°.

A trim indicator of the standard type, geared to the normal and emergency control wheels, indicates the amount of trim input by the pilot. However, above Mach .8, this reading will not be accurate, since the automatic tuck-under input is not reflected back through the cables. Therefore, a second trim indicator, operated by a potentiometer on the stabilizer, is mounted in the instrument panel. Both indicators show the same trim up to Mach .8; above this, the control-wheel indicator shows the pilot's trim input, and the panel indicator shows total trim. Both indications are useful in making a preflight check of the tuck-under trim system.





Fixed surface shroud raised to show regulator plug mounting and mating hole in balance board.

Flight Control Assist

The aerodynamic control forces acting on the tail surfaces of the Convair 880 in flight are quite large. Were it not for the fact that these are balanced down and trimmed out by assisting aerodynamic devices, the pilot would be hard put to exert enough strength on his controls to fly the airplane. As it is, the flight tabs, balance boards, and variable leakage regulator plugs combine in their action to remove excessive physical effort, providing the pilot with smooth integrated feel at the controls.

Spring-loaded flight tabs, located on the trailing edge of the rudder and elevator, are deflected by movement of the pilots' controls. The deflection of the tab is opposite that of the rudder or elevator movement so that flight tab movement assists in moving the main control surface. Physically, the pilot obtains approximately a 25-to-1 mechanical advantage by controlling the tab rather than the main control surface. In other words, a single foot-pound of pilot-applied tab hinge moment will produce 25 foot-pounds of aerodynamic hinge moment about the control surface.

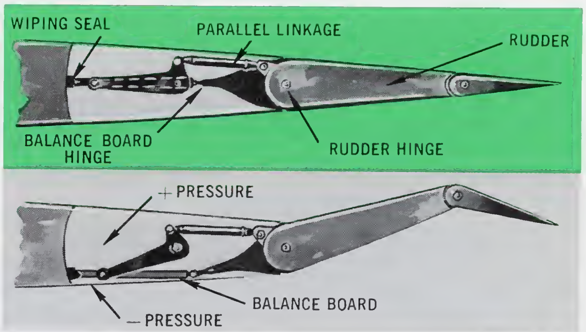
Forward of the hinge lines of the rudder and elevator, inside the vertical fin and horizontal stabilizer, are the balance boards. They are kept inside to minimize aerodynamic drag, and because their operation is predictable throughout the flight range and their forces can be modified as required. The balance boards impart forces ahead of the hinge line on the movable surface. Thus they largely balance the forces which act on the exposed portion of the flight control surfaces.

In principle, the balance boards act as aerodynamic pistons. The aerodynamic pressure built up on one side of the rudder or elevator when deflected, is allowed to enter the balance board chamber to exert pressure on the balance board. Similarly, the suction or negative pressure on the opposite side of the deflected control surface, draws from the opposite side of the balance board chamber. The combined pressure and suction forces acting on the balance boards are about equal to the combined pressure and suction forces acting on the exposed control surface. Thus, the balance boards work automatically to lessen the necessary forces exerted by the pilot.

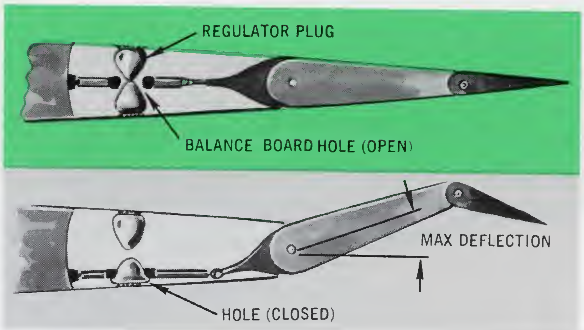
Balance board assist action is designed to permit full control surface displacement. The amount of automatic assistance from the balance boards at low angles of surface displacement is more than is required and would make cockpit control response too sensitive. For this reason, the variable leakage regulator plugs are installed.

The variable leakage regulator plugs are very simple and have no moving parts, yet they act to vary the force acting on the balance board. These cone-shaped plugs are mounted on each side of the stabilizer shroud. A circular hole with a seal is included in the balance board. At low angles of control surface displacement, the hole is wide open, relieving the pressure and suction delivered to the balance board chamber at low deflections. As the balance board moves to one side with larger control surface deflection, the tip of the plug enters the hole. In this manner, the hole is partially closed off. At full control surface deflection, the base of the regulator plug entirely seals off the flow of air between opposite sides of the balance board. The shape of the variable leakage regulator plugs permits just the right amount of force to build up for the desired feel at the cockpit controls.

The flight tabs, plus action of the balance board, give the pilot control over large control forces. The "tailoring" of the forces with the variable leakage regulator plugs causes the aerodynamic action to be smooth so that good pilot control "feel" results.



Schematic showing action of flight tabs, balance boards, and variable leakage regulator plugs.



HYDRAULIC GUST DAMPERS

Hydraulic gust dampers installed in conjunction with the control surfaces of the Convair 880/990 jet airliners provide a means of preventing winds and gusts on the ground from activating and possibly damaging the airplane control surfaces. This design feature does away with conventional control chocks and locks, and enables the control surfaces to swing in the wind without damage.

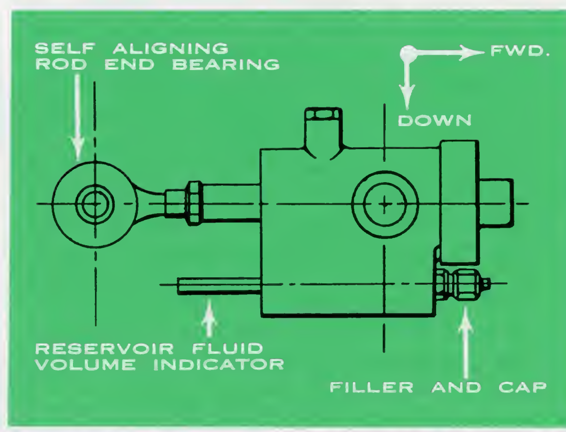
A total of five gust damper units are installed on Convair 880/990 airplanes. One unit is connected to the rudder and is located at the base of the vertical stabilizer, one is connected to each of the elevators and is located on the stabilizer spars, and one is connected to each of the ailerons and is positioned at the rear spar adjacent to each aileron.

The gust damper is a self-contained unit, requiring no hydraulic line connection to either hydraulic system. Each has its own reservoir which may be serviced with a ground cart when required. A plunger at the end of the filler connection has an index for checking the fluid level (MIL-L-5606.) The spring pressure from the spring-loaded reservoir is used to constantly service the main cylinder area if the cylinder requires fluid.

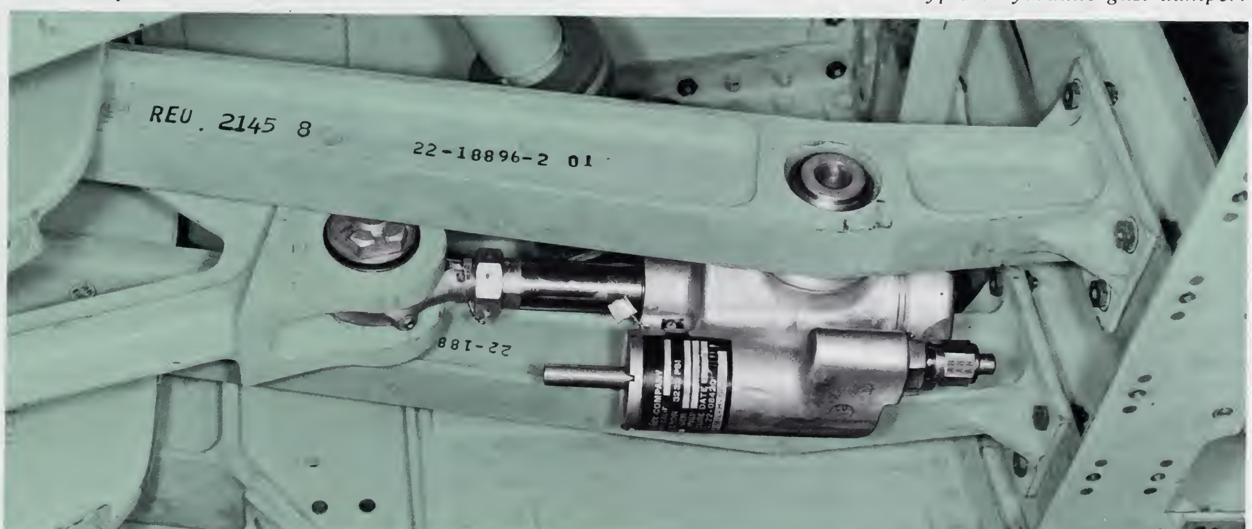
The cylinder of the hydraulic gust damper contains a piston that extends through one end of the cylinder and connects to the respective primary control surface. Small bleed orifices drilled in the piston permit hydraulic fluid to pass from one side of the piston to the other, thereby damping any ground gust load that might occur. The dampers are connected to the control surfaces in a manner that will allow the damping to increase proportionately with an increase of primary control displacement from trail.

The gust damping system of the Convair 880/990 is constantly in effect, regardless of control movement or position. However, as long as the controls are operated slowly, the damping effect of the system is negligible and does not interfere with pilot control of the airplane. The system protects the flight control surfaces against sudden, rapid movements such as those imposed by gusts and winds, and as long as slow, coordinated control movements are executed, the presence of the damping system is not evident.

The Convair 880/990 hydraulic gust damper was designed by Convair engineers, and is currently being manufactured by the Carl Drescher Company. The configuration of the rudder unit differs slightly from those used on the control surfaces, but the principle and function of each damper is the same.



Typical hydraulic gust damper.



Hydraulic gust damper installed on "880" aileron. Unit prevents damage from sudden forces.

Flight Control Windlock During Ground Check

About the time he straps himself into his seat, the pilot of a Convair 880, like most other pilots since the Wright brothers first flew, will probably automatically work his flight controls a time or two, to be sure they feel normal and are not binding. If there is wind from any direction except straight ahead, he can expect to feel it in the controls, the more so because the surfaces are all tab-operated and the leverage exerted directly on the main surfaces is much reduced.

What the pilot may not expect to find is that a relatively small tail wind can sharply limit the travel, or even appear to jam completely, a perfectly normal control linkage. This might occur in an "880," as it does in some other aircraft with large manually-operated control surfaces.

Either rudder or elevators may be affected; the ailerons are less susceptible. A brief analysis of rudder mechanisms will serve to show how it happens.

In a normal ground check from the flight deck, the rudder pedals will first move the flight tabs through a range of 42°, 21° to either side of streamline. If the pilot wishes, he can move the rudder itself. Tab travel limit is established by a stop, contacted by the rudder hinge line bellcrank. The stop is attached to rudder structure; therefore any further pressure on the pedal will be fed through the stop to the rudder main surface. In still air, normal pilot foot pressure is sufficient to move the rudder through some portion of its travel.

Moment arms of the bellcrank linkages are engineered primarily to move the tabs. Moment arm at the rudder hinge line bellcrank, on the pedal side, is approximately 3½ inches maximum. Transmitted to the flight tab, this moment will move the tab against almost any wind; but when the force is applied to the rudder directly, the moment arm is reduced by partial rotation of the bellcrank. Also, rudder surface is ten times that of the tab, and aerodynamic forces are multiplied accordingly.

Let us say that a wind blows the rudder to the right, as in the illustration. It will probably deflect only 14°, at which point it contacts a spring in the gust damper. The centering spring tends to hold the hinge line bellcrank — and the pedals — at neutral or streamline position; therefore the flight tab will "anti-servo" — deflect on toward the right another 14°, leaving the pedals at streamline position.

Now, should the pilot push down on the left pedal, he will without difficulty move the flight tab to the right, in the normal direction for left rudder, to the 21° limit of tab travel — only 7° more. To push the pedal down farther, he would have to move the rudder back to streamline by leverage on the tab stop. Since the wind can easily exert enough force on the large surface to counteract the pilot's foot pressure, his pedal travel will appear limited to 7° from streamline.

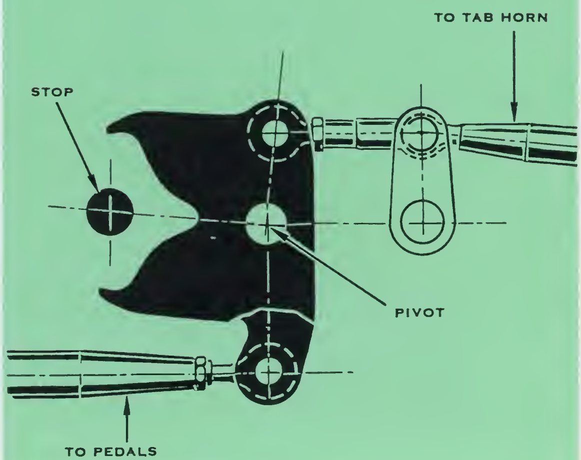
But when he pushes the right pedal, he will be able to move the tab toward the left against the wind, first the 14° to streamline, then on left to 21° full deflection — 35° altogether. He still has 42° of effective travel, 7° left and 35° right, but his center reference has been shifted; and he will not be able to move the rudder itself at all.

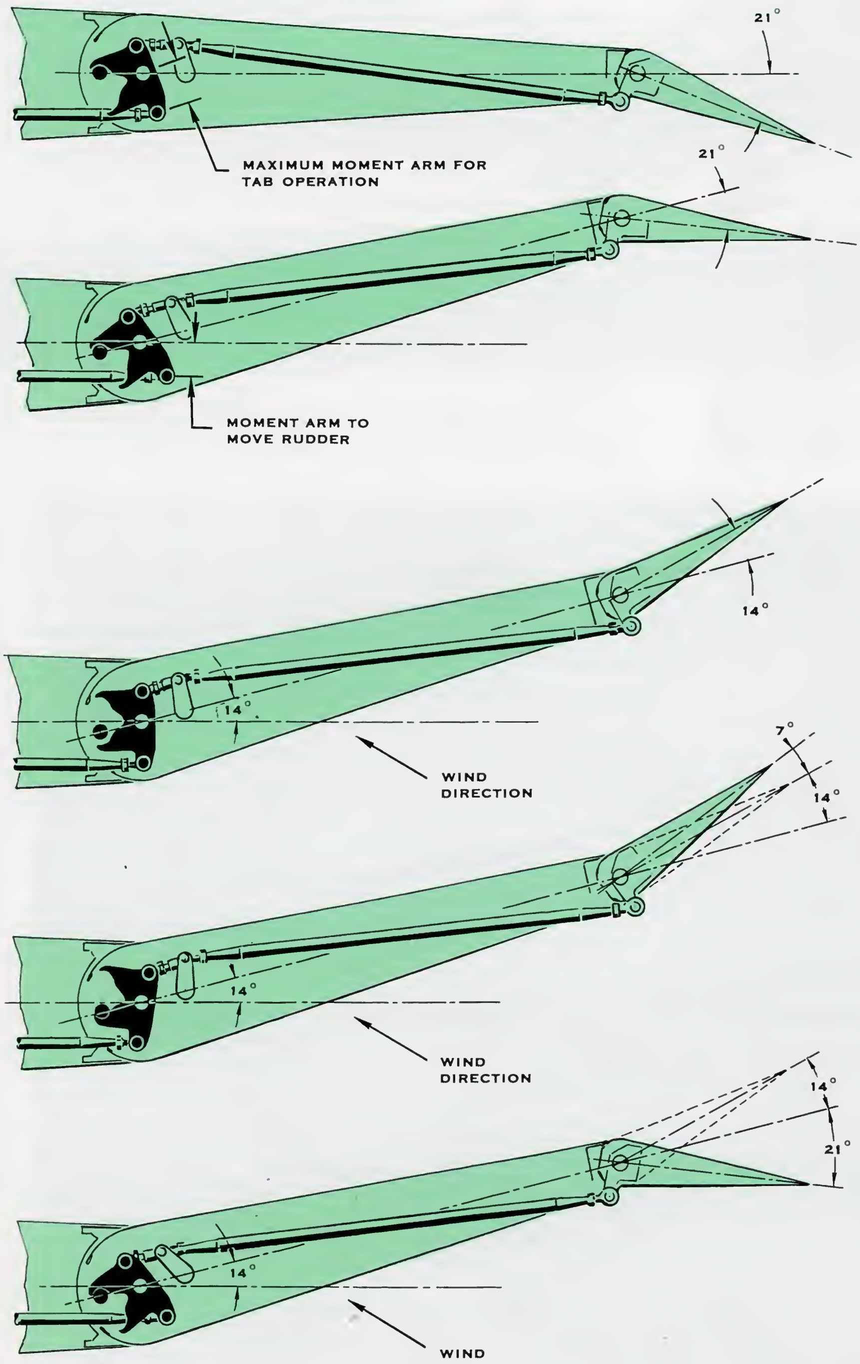
In the case of elevators, cockpit control may similarly appear normal or more than normal in one direction, but impossible in the other. The elevators are not directly interconnected. If one elevator should be blown up and the other down, the control column might appear almost solidly jammed in one position.

The aileron system is designed purposely to provide a ground check. The pilot moves the control wheel to a certain travel, depending on the position of the ailerons, and then the tab bellcrank at the aileron hinge contacts a "ground check bar" and drives the aileron to full deflection, visible to the pilot. Leverage on the check bar is enough that only a very strong wind could lock the ailerons.

As long as the "wind-lock" effect is known and anticipated, it should cause little inconvenience. When it happens, the airplane should always be turned into the wind for a recheck before takeoff. If then the controls do not move normally, or if any control does not operate normally in still air, takeoff should be held up until the cause is found and eliminated.

Detail Of Bellcrank





Normal check, right rudder applied, tab deflected until bellcrank strikes stop.

Bellcrank force on stop then deflects rudder.

When rudder is blown by wind, bellcrank may remain at streamline position.

Left rudder applied, wind force holds rudder hard right.

Right rudder applied, pedals act normally, rudder deflected to right.

Schematic - Rudder And Tab Linkage During Ground Check

Rudder Rigging Tools Convair 880

The Convair 880 production line employs a rigging tool (in three parts), for checking the rigging and operation of rudder controls. This tool is designated RGTL 22-15000-901.

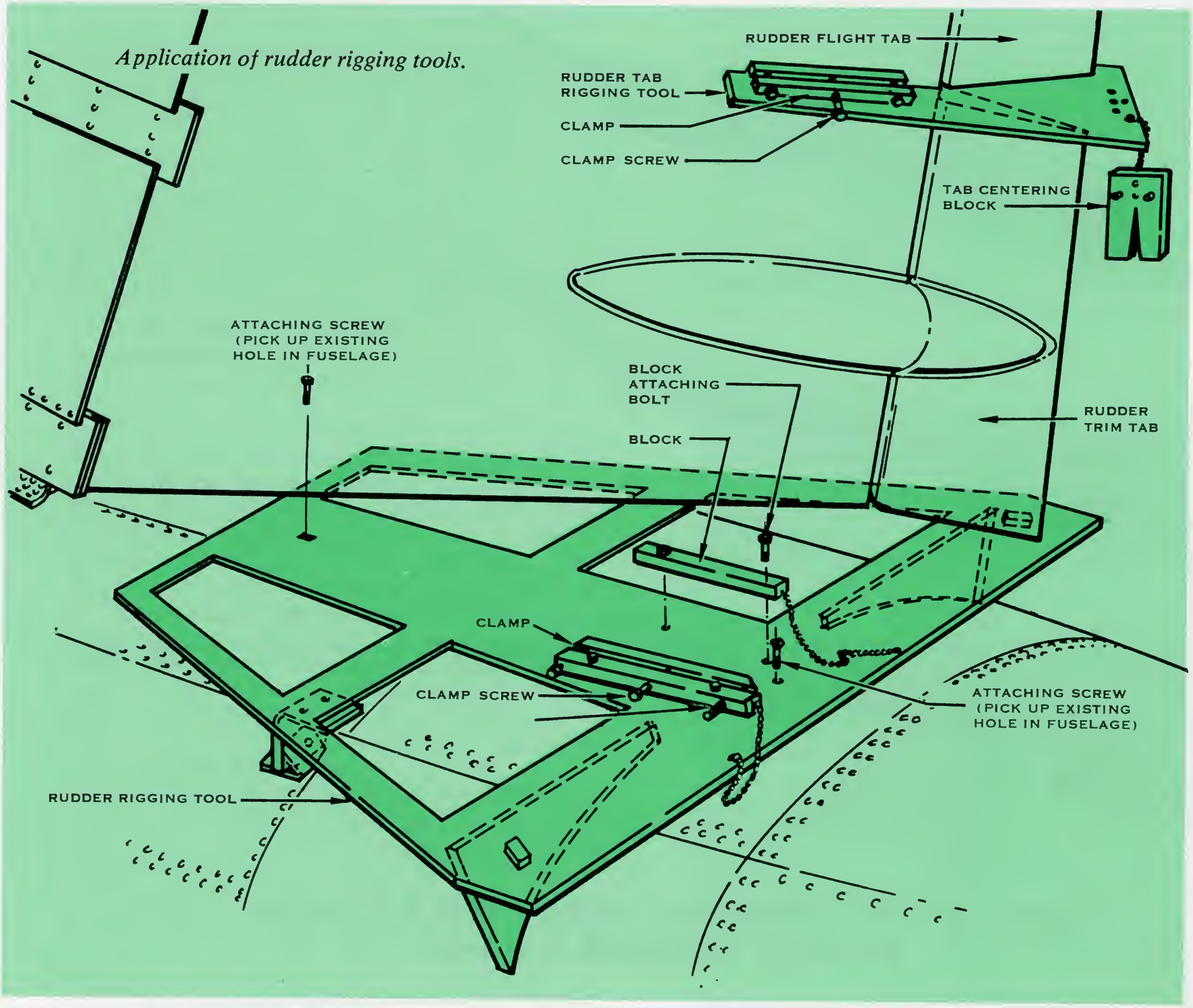
RGTL #1 is a flat aluminum plate, marked to show the streamline position and left and right full throw of the rudder. The tool can be used to lock the rudder in any one of these positions. When in position on top of the fuselage just under the rudder, it is held normal to the rudder by a base that is contoured to fit the fuselage at this point. Holes in the centerline of the tool correspond to screw locations at buttock line 0.00, station 1481.65 and 1511.65, on top of the fuselage. These holes are used for tool alignment.

RGTL #2 is a similar plate (without base), graduated to show degrees of tab movement. The top side of the plate contains gradations for the rudder flight tab; the lower surface contains gradations for the trim tab. The plate is equipped with blocks on the forward edge which clamp the plate to the rudder between the two tabs. In this way, both the rudder trim tab and rudder flight tab may be checked simultaneously.

RGTL #3 is a small block of 3/4-inch aluminum, resembling a truncated triangle 3.500 +.000, −.010 inches across the rounded corners of the base. It is notched and fitted with a screw hook and a hole to permit it to act as a lock on the flight tab. The two forward bolts are removed from the rudder hinge line bellcrank support assembly when the tool is used. The hook is placed around the aft side of the stop and tightened by means of a nut on the screw hook. This clamps the tool securely to the rudder flight tab stop so that the rounded corners of the tool bear firmly against, and hold, the hinge line bellcrank in neutral position.

Tool drawings may be obtained from Convair for local manufacture of the rudder rigging tools.

Application of rudder rigging tools.



the CONVAIR "880" LANDING GEAR

The Convair 880 has been designed to meet the needs of many of today's airlines for a modern high-speed transport with maximum performance flexibility, combined with adaptability to present day airport facilities.

For operators and passengers alike, this means economy and convenience, and eliminates the necessity for costly alterations and revision of routes.

An important factor contributing to adaptability of the "880" for use at already existing operator facilities lies in its landing gear, which is designed with simplicity, strength, and dependability as primary considerations.

Shorter landing distances can be realized with the help of efficient disc-type brakes on nose and main landing gear wheels, and through the use of an anti-skid control system.

Maximum takeoff and landing loads are handled capably and safely with dual tandem wheel assemblies on each main gear, and dual wheels on the nose gear. The oleo struts used on the main and nose gears are of the hydraulic-pneumatic type, and incorporate a metering device to absorb high-speed impacts safely during takeoffs and landings, assuring maximum passenger comfort.

All three gears retract into wheel wells which are closed by wheel well doors. The main gears retract inward into the fuselage; the nose gear retracts forward into the nose of the airplane.

The main gear, designed to permit positioning of the double trucks, allows the rear wheels of the truck to contact the runway surface first when the airplane is landed, and it allows "rocking" to compensate for airplane attitude changes during taxi, takeoff roll, and landing roll. This is accomplished by a hydraulic-pneumatic centering device, or positioner. This device also positions the double trucks so that they will be in the correct attitude within the main wheel wells upon gear retraction.

Fore and aft brake links are installed to eliminate any pitching tendencies that might occur as a result of excessive braking, and to equalize load distribution on both forward and aft trucks when brakes are applied. An emergency air cylinder is installed to supply emergency braking power.

Through the use of a Hytrol anti-skid system, brake control is automatic. This permits reduction of the landing roll to a theoretical minimum, regardless of pilot skill. As a result, overcautious use of brakes to prevent skidding during landing is eliminated, and there is no tendency for overbraking which, without an anti-skid device, could result in a locked wheel condition.

With the automatic brake control system, the "880" can land safely on shorter fields with wet or dry runways and, at the same time, obtain maximum braking efficiency regardless of airplane weight or coefficients of friction. With the anti-skid system, the pilot can apply a full steady brake pressure until the airplane comes to a stop. This relieves him of the necessity for determining the proper time for brake application.

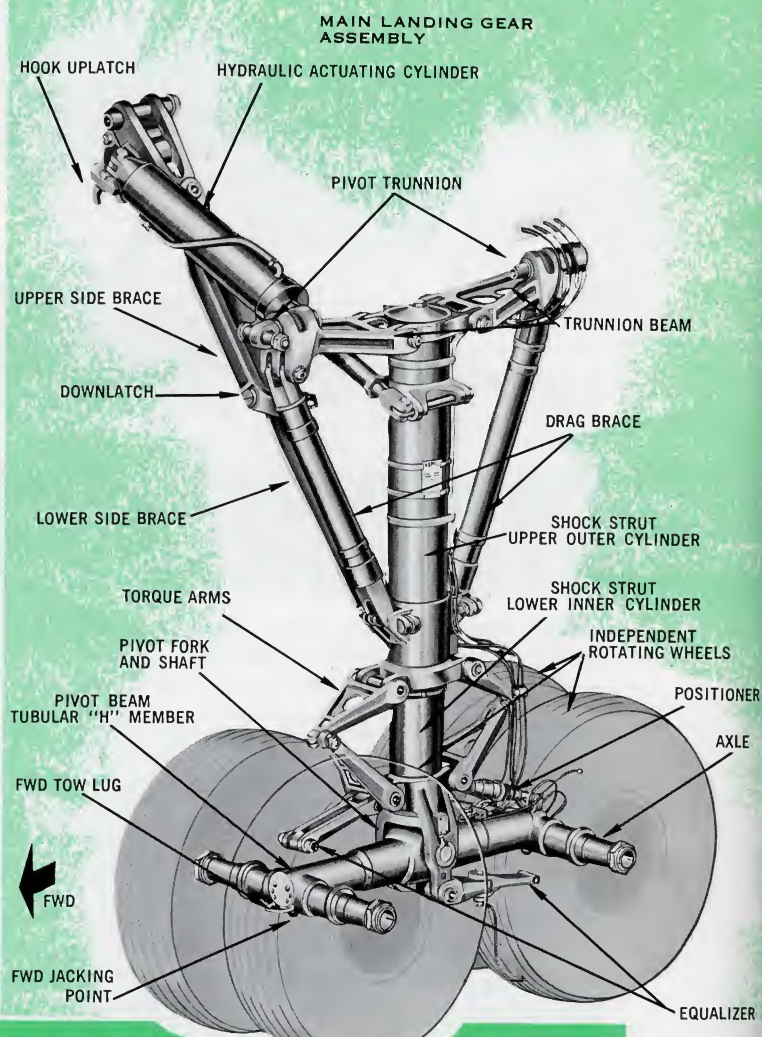
The main landing gear is constructed of quickly replaceable components, which may be used on either right or left gear assemblies. An assembled right gear, for example, may be installed on the left-hand side if the upper fore and aft members of the drag brace assembly are reversed. Among interchangeable components of the main gear are struts, wheels, brakes, tires, and anti-skid units. In addition, wheel well doors and door mechanisms are interchangeable. Left and right components of the nose gear are interchangeable as are the doors and door mechanisms.

Precisely machined, high heat-treat steels and high-strength aluminum alloys are used in the construction of both main and nose landing gear assemblies. All non-rotating joints have electrofilmed bearing surfaces; all rotating joints have chrome-plated bearing surfaces. Replaceable bushings are provided at all points.

All components of the "880" landing gear system have been designed to function perfectly in all climatic conditions, without adverse effects being created by water, snow, sleet, hail, ice, salt spray, sand, and dust. The entire system is designed to accommodate disassembly, reassembly, and servicing, utilizing tools and replacement components which are available as commercial standard.

Lubrication is provided throughout the landing gear system, and all those areas that may be susceptible to the entry of foreign matter have been sealed. Pressure lubrication fittings are provided at all points that are subject to friction and wear through the movement of mechanical parts.

Basic landing gear assemblies are manufactured to Convair design specifications by the Cleveland Pneumatics Tool Company. These units accommodate Bendix wheels and brakes and anti-skid control units.



MAIN LANDING GEAR

The main landing gear incorporates eight wheel and brake assemblies, four on each gear. The wheels on each side are mounted in tandem pairs. All wheels rotate independently, each incorporating an individual brake assembly. The four wheels are mounted on axles inserted in a tubular "H" member which, in turn, is suspended in a fork that forms the lower end of the shock strut inner cylinder. The truck thus formed can rock in fore and aft angular relationship to the shock strut.

The shock strut, which is of the hydraulic-pneumatic type, consists of an upper outer cylinder and a lower inner cylinder. Both upper and lower cylinders are machined and shot-peened tubular steel forgings. The lower cylinder has two lugs which adapt the shock strut to the truck beam assembly; the upper cylinder provides attach points for the drag and side braces.

The degree of shock strut compression is dependent on airplane gross weight and loading for center of gravity location. Full stroke of the shock strut is 16 inches.

The drag strut, the outer cylinder of the shock strut, and the trunnion beam form a pin-ended "A" frame which distributes the load along the axis of each member. This method of construction braces the gear and increases structural integrity.

Outward movement of the landing gear is restricted by a double-link side brace which is attached at its lower end to the main shock strut, and at its upper end to the wing structure. The side brace assembly, which consists of aluminum alloy brace members and a steel downlock mechanism, also provides rigid support to the gear structure and positively locks the gear in the extended position.

The gear is suspended from two pivot trunnions, located in the fore and aft ends of an inverted triangle, formed by the trunnion beams and two tubular drag braces. The drag braces are attached fore and aft between the trunnion beam and main shock strut. Thus, during landing gear extension or retraction, the gear moves at right angles to the longitudinal axis of the airplane.

The gear is actuated hydraulically by means of a cylinder which is attached to a lug on the shock strut and to a point below the pivoted upper end of the side brace. Pressure supplied to the outboard side of the cylinder causes inward movement of the piston.

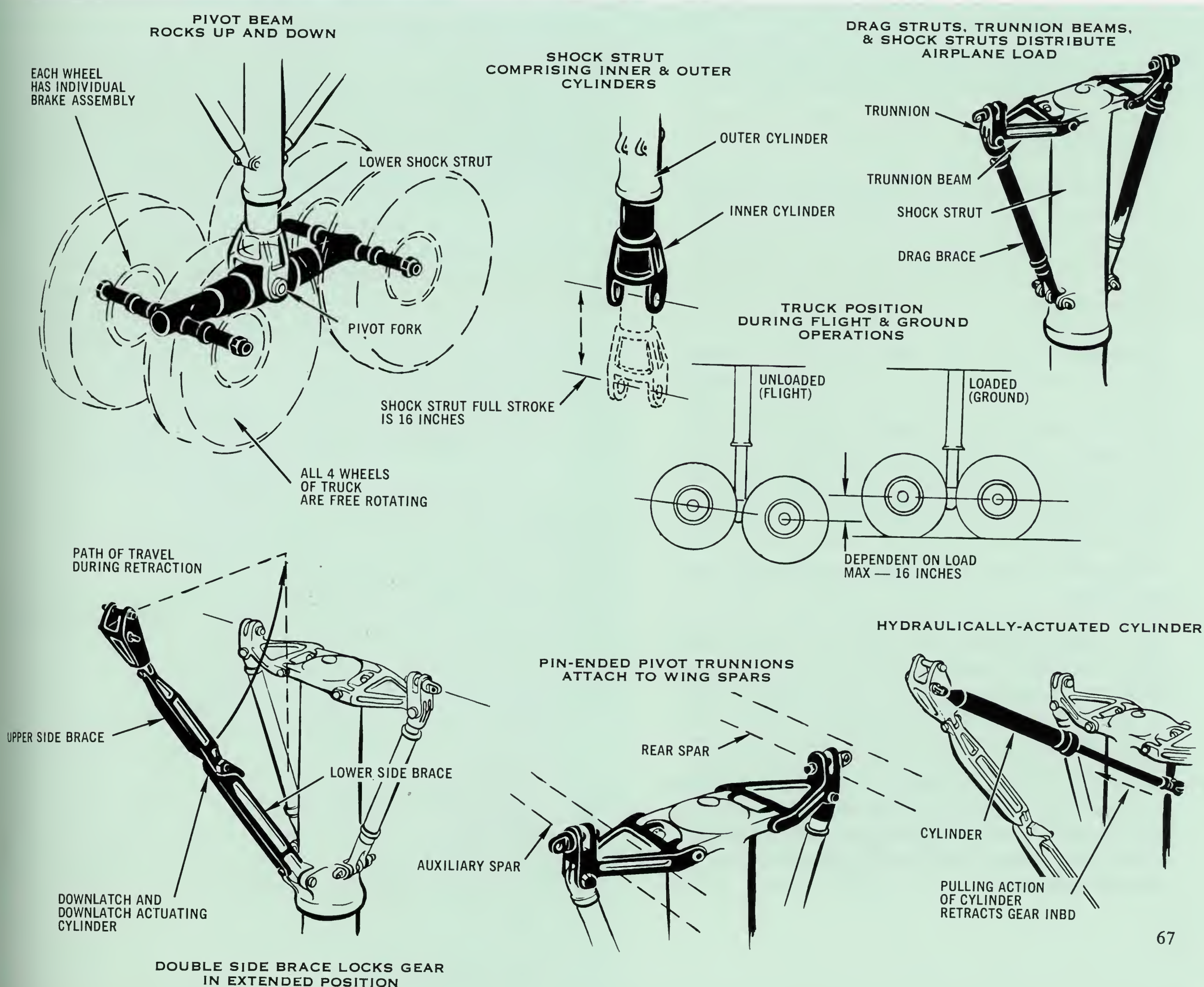
The mechanical advantage gained by the location of the actuating cylinder attach points causes the center pivot of the two side brace sections to move upward, pulling the shock strut and double-truck assembly inboard.

The main landing gear is designed for use as an alternate speedbrake at speeds up to 375 knots. When used as a speedbrake, the main landing gear *only* is extended.

The main landing gear doors are designed to close when the gear is extended in flight so as to decrease drag. A sequencing device is incorporated in the door mechanism to open and close the doors when the gear is retracted or extended.

A complete cycle of main landing gear operation includes doors open, two seconds; gear extended, six seconds; doors closed, two seconds. Total time required is 10 seconds. Gear actuation is described elsewhere in this issue.

Each main gear truck has three jacking points: one located between each of the wheel pairs, and another at the bottom of the strut. Because of suspended double-truck design, it is possible to jack either main wheel pair without raising the other pair. This feature permits use of a small capacity jack, and facilitates tire and wheel maintenance. Tow lugs are provided on the forward and aft ends of each main gear axle beam assembly.



NOSE LANDING GEAR

The hydraulically-retractable nose landing gear is of dual wheel design, incorporating co-rotating steerable wheels, brakes, and anti-skid features. The assembly, when retracted, is enclosed by doors on the fuselage structure and by a fairing on the strut.

The doors are designed to remain closed at all times in flight to reduce noise level, except when the gear is in transit. The doors are closed when the gear is extended; however, means are provided for opening these doors on the ground for access to the nose wheel well area. If the doors are inadvertently left open, prior to takeoff (after having been opened for ground access) normal retraction of the gear will cycle the doors to the closed position, and they will remain closed with the gear up.

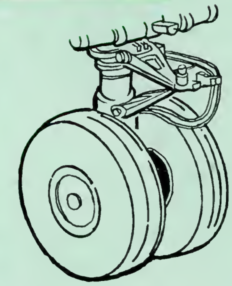
Similar structural concepts used in the main gear are applied to the nose gear assembly. Identical side bracings are pin-ended, forming an inverted "A" frame on each side of the shock strut. This feature provides a load path directly into the support structure, and eliminates bending across the trunnion beams. As in the main gear, maximum load is distributed within the members to assure structural integrity.

The nose gear wheels are mounted on fixed stub axles, integral with the shock strut lower end. An internal torque tube, which couples the wheels, provides co-rotation. This feature has the advantage of utilizing standard wheel bearings, and eliminates fatigue problems.

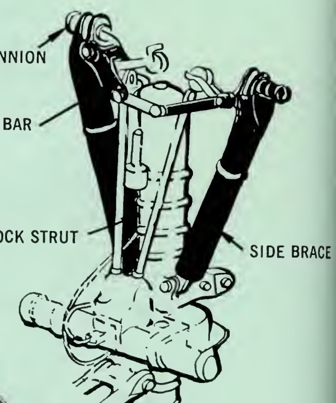
Retraction of the nose gear assembly is accomplished by means of a hydraulic cylinder connected between arms attached to the tops of the right shock strut side brace and the right upper drag brace. Extension of the cylinder piston rotates the drag brace and shock strut in opposite directions and causes the drag brace to "break at the knee" and the wheels to move up and forward into the wheel well.

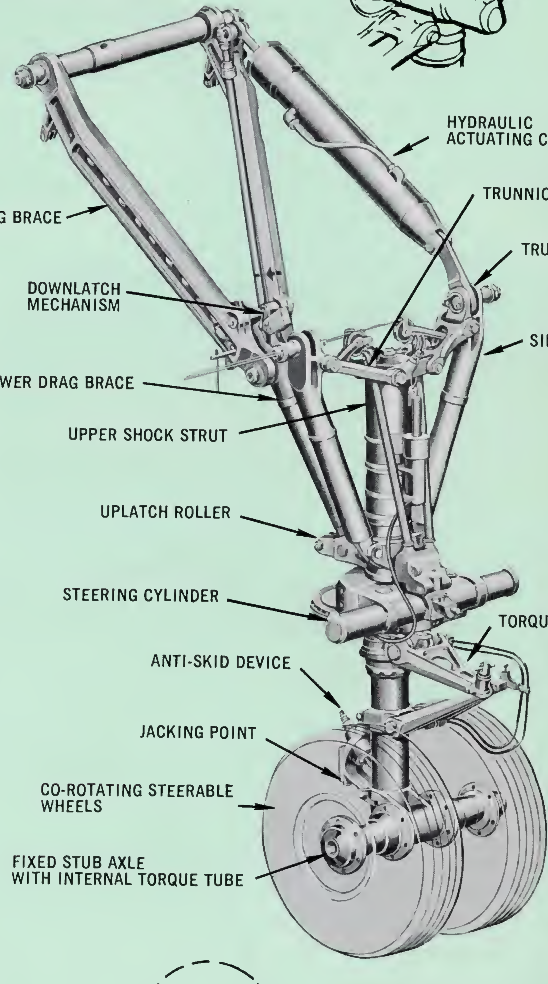
There is a single jacking point under the nose shock strut.

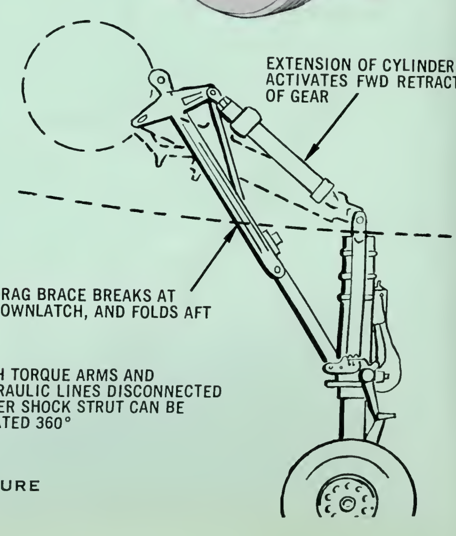
For towing purposes, a tow bar can be attached to hollow bushings (cups) at each end of the nose wheel axle. With torque arms and lines disconnected, the nose strut can be turned 360 degrees. Quick disconnect features permit "breaking" the torque arms and hydraulic and electrical lines at the apex point so as to facilitate maintenance operations. During normal towing operation, the airplane is capable of being turned up to 90 degrees each side of center without the necessity of detaching the lines at the quick disconnects.

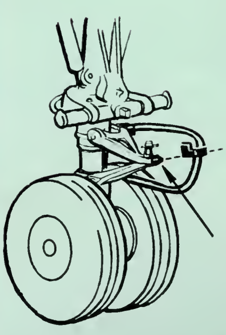


CO-ROTATING STEERABLE WHEELS COUPLED BY INTERNAL TORQUE TUBE EACH WHEEL INDIVIDUALLY BRAKED

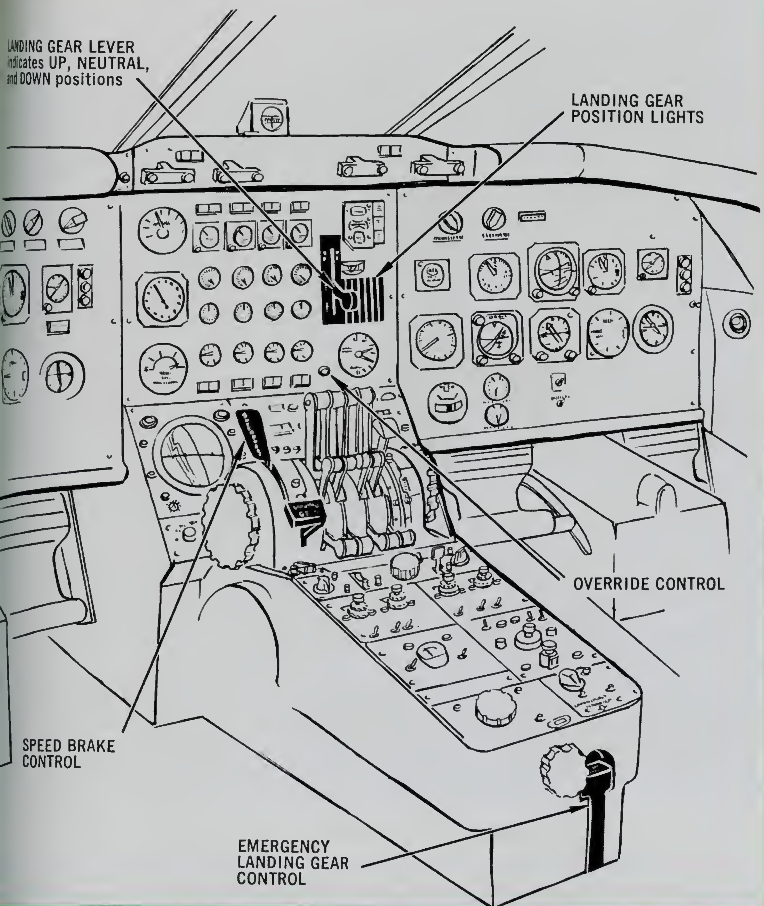




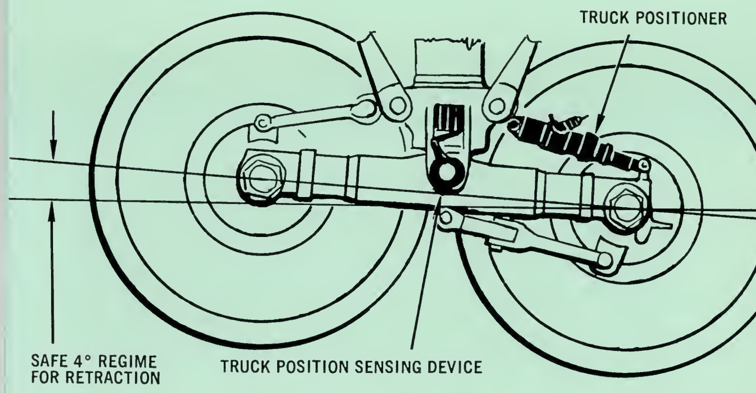


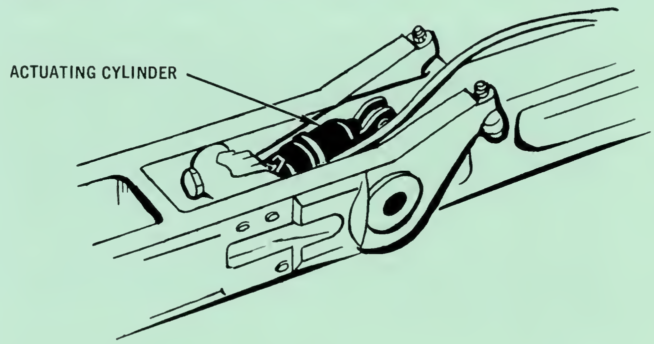


QUICK-DISCONNECT FEATURE SPEEDS SERVICING



MLG TRUCK POSITIONING MECHANISM





MLG DOWNLATCH AND PIVOT POINT

GEAR EXTENSION and RETRACTION

Gear extension and retraction is controlled by a single lever located on the right-hand side of the center instrument panel. The lever has three positions: Up (retracted), NEUTRAL, and DOWN (extended). In flight, the landing gear lever is placed in the NEUTRAL position to remove hydraulic pressure from the system. When the airplane is on the ground, the landing gear control lever is mechanically safetied in the DOWN position by action of a solenoid safety circuit from the landing gear to the safety lock solenoid.

Whenever the shock struts are compressed (airplane on the ground), the solenoid is deenergized, and the solenoid pin is allowed to extend, preventing the landing gear control lever from being inadvertently moved to the NEUTRAL or UP position. When the load is removed from the landing gear shock struts, as in flight, the solenoid is energized, retracting the pin. An override button on the solenoid pin permits raising the control lever in the event of solenoid failure.

The main landing gear truck assembly must assume an optimum attitude in relation to the horizontal plane, prior to landing. It must also assume the correct position for gear retraction, and it must be allowed to "rock" to compensate for airplane attitude changes during taxi, and takeoff and landing rolls. The overall "rock" permitted is 16 degrees. The optimum regime has been established with the truck at an angle of 4 degrees, nose up.

Proper positioning is accomplished by installation of a hydraulic-pneumatic centering device, called a positioner. The positioner is a small cylinder assembly that is partially filled with hydraulic fluid and charged to 1600 psi for a combined cushioning effect.

In order that the pilot may know when the truck is in proper position for gear retraction, a positioner indicating system is installed. The system consists of a rotary type switch mounted on the shock strut inner cylinder which, by means of a linkage, senses the angular position of the main truck pivot shaft. The switch actuates a signal which indicates a "safe" or "unsafe" position of the truck. In addition, an interlock circuit prevents movement of the landing gear selector to the UP position unless the truck is in the "safe" 4-degree regime. An override is provided to cancel action if the gear must be retracted in an emergency flight condition.

The latches automatically lock in the DOWN position when the joints in the side brace of the main landing gear and in the drag brace of the nose landing gear are straightened. Release of the downlatch is accomplished by a combination of hydraulic and mechanical forces in that a mechanical release

linkage is actuated by a hydraulic cylinder, which in turn is energized by pressure transmitted to the UP side of the main actuating cylinder.

The nose landing gear uplatch operates by a combination of mechanical and hydraulic action. Mechanical movement of the hook, by contact with the upcoming roller on the strut, triggers the hydraulic locking action. The hook is connected by a linkage to the lock assembly actuating cylinder. When the gear is extended, the hook is always in position to receive the upcoming gear.

In an emergency, free fall and positive locking of the gear is provided. The emergency system is mechanically and pneumatically operated. When the emergency control handle is moved toward the landing gear down position, the main gear doors are pneumatically opened and the nose and main landing gear uplatches are mechanically opened, allowing the gear to free fall and lock. A separate air pressure source is provided to open the landing gear doors in this event.

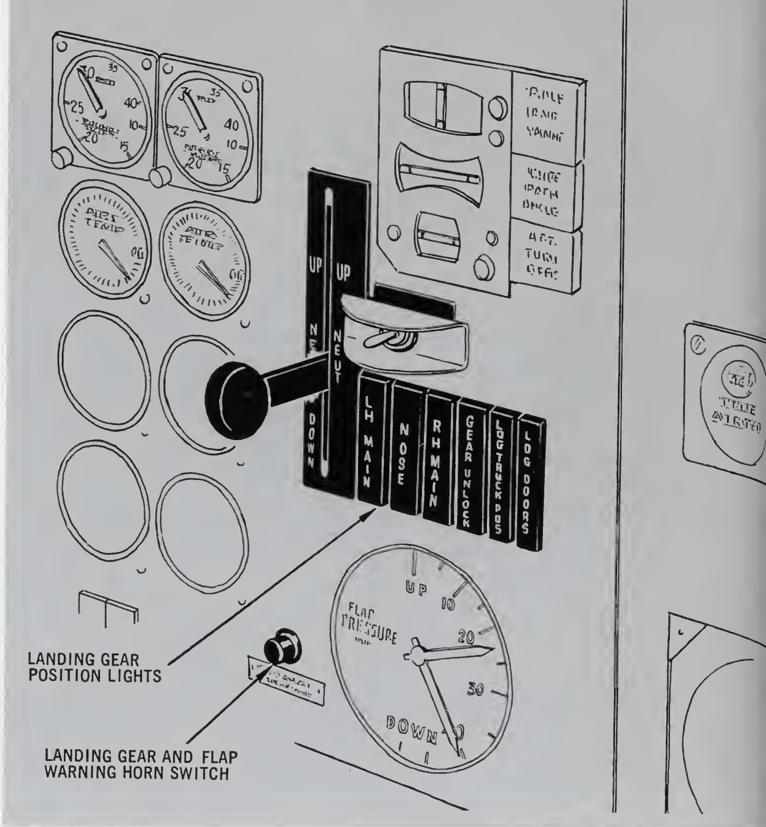
The handle for lowering the main landing gear for speedbrake operation is located adjacent to the speedbrake/spoiler control. Aft movement of this handle actuates a differential mechanism which moves only the system of cables that will actuate the main landing gear control valve for the landing gear actuator. Although the speedbrake control connects into the landing gear system, it does not affect any of the interlock, warning, or emergency systems.

If the landing gear speedbrake handle is in the extended position, retraction of the normal landing gear handle will raise only the nose gear.

To extend the nose gear, when the main gear has been extended for speedbrake operation, it is necessary to operate the normal landing gear lever on the pilots' instrument panel to ALL GEAR DOWN position.

GEAR INSTRUMENTATION

Landing gear position lights are installed on the right-hand side of the center instrument panel, near the landing gear control lever. A dual-bulbed warning light system is provided and a double warning indication is available for the main gear. The signal system is connected to the landing gear locks in such



a way that a single green light for each gear is illuminated when the gear is extended and locked. The main gear doors cannot be closed until the main gear downlock mechanically actuates the door sequencing valve. Unless the sequence valve is actuated, the door light will remain on. In addition, the main gear "unsafe" light will remain on, indicating that the door is open and the gear is in an unsafe condition for landing.

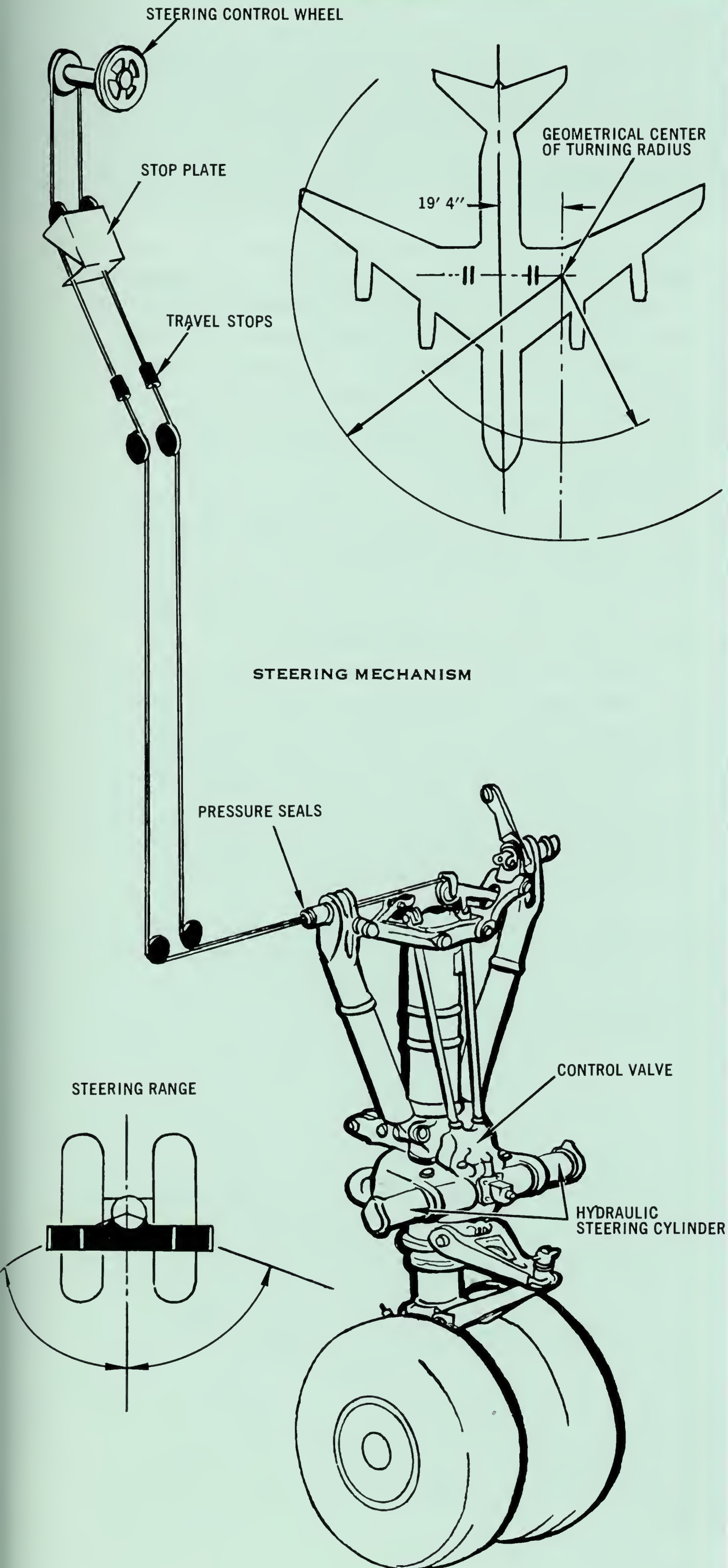
The nose gear door is connected directly to the nose gear mechanism; therefore, gear-down-and-locked-position indication only is available. A covered hole for viewing the nose gear downlock is provided in the bulkhead web in the aft end of the nose wheel well. Access to the viewing hole is through a floor panel in the flight compartment.

When the landing gear is extended and locked for speedbrake purposes, a green light for each main gear is illuminated to indicate that the main gear is down and locked; the red "gear unsafe" light is illuminated to indicate that the nose gear is still in the retracted position.

In addition to the lights, a horn is installed in the pilots' compartment to sound a warning to indicate that the gear is not fully extended and locked, when any one power lever is reduced below the 25 percent thrust position, and the flaps have not been extended for landing position.

The electrical components for the position indicating system are sealed and protected against entry of water, ice, and foreign materials. They are located and protected to guard against damage from ground handling equipment.

NOSE LANDING GEAR STEERING



A hydraulically-operated steering unit, with a powered steering range of 70 degrees each side of center, is installed on the nose landing gear. The geometrical center of the turning radius is 19 feet 4 inches outboard of the airplane centerline, and is located on a line through the centerline of the main landing gear oleo struts. The radius of the wing tip about the turning point is 84 feet.

A centering cam on the nose landing gear shock strut returns the nose wheels to the centered position when the weight of the airplane is off the gear and the strut is extended, thus insuring that the wheels are always centered when the gear is being extended or retracted.

The steering unit is of the rack-and-pinion type, completely enclosed to protect against contamination from dust, splash, and exposure to weather. This hydraulically controlled and actuated assembly is mounted on the cylinder of the shock strut. Stationary "wear bushings," keyed to the strut, provide maximum strut protection from steer-collar wear. Adjustment is provided to take up end wear on steering collar bushings.

The assembly consists of a control valve, actuated by a chain and cable system from a cockpit steering wheel, and a dual actuating cylinder assembly. The mounting of the hydraulic control valve directly onto the actuator has the function of follow-up action by closing the valve flow. The lower member of the torque arm assembly is attached to the inner cylinder of the shock strut, which rotates within the outer cylinder. On the inner cylinder and axle assembly are suspended the dual wheels, which are limited to a 140-degree total steering travel.

A hand wheel, located on the left-hand console within easy reach of the pilot, controls the steering unit. A shutoff attachment automatically releases the brake if the nose wheel is turned beyond five degrees. The neutral position of the gear is indicated on the wheel.

The steering cable arrangement is so designed that a directional sense of control is evident to the pilot.

Pressure for hydraulic steering is obtained from the No. 1 hydraulic system, with provisions for automatic closure of the steering circuit from the main system whenever the gear is retracted. Loss of nose wheel steering pressure automatically renders the nose wheel brakes inoperative. In this event, steering is possible by differential braking.

BRAKES

Main gear brakes are "free floating" on the axles. This design eliminates the multiple bolt flange arrangement for connecting the brake to the shock strut. Brake equalizer bars on the main landing gear transmit brake loads into the shock strut to prevent pitching the brake loads onto the front pair of wheels in the truck.

Air scoops are provided on each brake carrier to provide air flow to the brake, through vent holes in the brakes and wheels.

Because of the intense heat generated during some emergency brake applications, brake linings of improved materials are used. The multiple-disc brakes, constructed of three basic materials, consist of segmented rotating and stationary friction discs. Rotating discs, alternately stacked with stationary discs, are keyed to the outer rim of the brake assembly; the stationary discs are keyed to the inner torque tube. When the discs are forced together, compressing the stack so that all faces are contacting, braking action is imposed on the wheel.

Compression of the stack is accomplished by means of interconnected hydraulic pistons. When pressure is applied, the pistons impinge on one side of the pressure plate, forcing the opposite side to contact the rotating discs of the stack. When pressure is released, a ring of tension spring cartridges, attached to the pressure plate, releases the pressure plate, freeing the disc stack, thereby returning the pistons to neutral.

Because the brakes are self-releasing through spring action, no adjustments are necessary. Friction components are readily disassembled by removing the ring of "brake bolts" which penetrate the assembly housing portions that hold the brake together.

The nose wheel brakes are rigidly mounted on a forged brake plate, forming a portion of the inner shock strut cylinder. The main wheel brakes are flexibly mounted on large bushings to permit deflection of the main wheel trucks. Their load is transmitted to the airplane structure via the equalizer links.

Both main and nose wheel brakes are controlled by means of toe pressure on the upper portion of the rudder pedals. Levers, integral with the brake portion of the pedals, are connected to push-pull tubes, which extend down to cranks where the motion is carried back to two torque tubes, each pedal being linked to a separate torque tube. The tubes continue across the airplane to join an identical system provided for the copilot's rudder pedals.

From each torque tube, a cable system on each side of the airplane is routed directly aft to a set of pulleys, located in the main wheel well. Push-pull tubes from the pulleys operate control valves for the main wheel brakes.

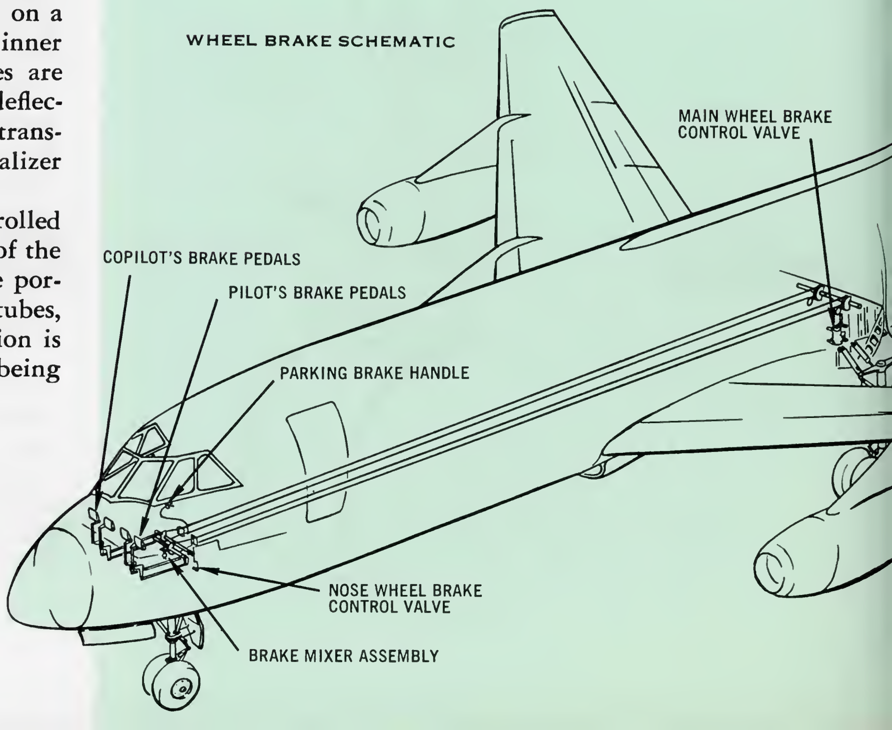
A pull-type handle (spring-loaded to "brakes off" position) on the left-hand side of the pilots' compartment panel is used to lock the brakes for parking. To set the parking brake, it is necessary for either the pilot or copilot to depress both brake pedals and then pull the handle. This action engages a notch with a pin in the brake linkage. The spring return force, on the brake linkage and on the parking brake linkage, maintains engagement of the notch and pin to set the brakes. When the parking brake lever is pushed down to "brakes off," the notch and pin are disengaged and the main brake mechanism is released.

Emergency brake operation is provided by pneumatic pressure obtained from an air flask mounted in the nose gear wheel well. Rotational movement of the brake control valve on the left console meters pneumatic pressure to each of the eight main wheels when the emergency system is utilized.

Brake wear may be checked without removing the wheels or disassembling the brakes. The brakes are provided with a self-releasing spring mechanism, eliminating the necessity for clearance adjustments.

A safety feature hydraulic valve is provided which renders only the nose brakes inoperative, when the steering control rotates the nose gear beyond approximately five degrees, either side of neutral.

WHEEL BRAKE SCHEMATIC



Convair 990 Landing Gear

The evident family resemblance between Convair 880 and 990 jet airliners may obscure the fact that there are a number of structural differences not apparent at a glance. This is particularly exemplified in the landing gears of the two aircraft.

With the airplanes side by side, it can be seen that the "990" main gears are longer and heavier. A closer look will show that the gear is a new design. The aft drag brace has been eliminated. Downlocks on "990" main and nose gears are in jury braces between the folding elements and the struts, rather than in mechanisms at the "knees." Retraction mechanism of the nose gear is completely different.

Differences in materials and operation are less apparent. The "990" main gears carry approximately a third more weight than the "880" main gears. They are structurally designed for maximum taxi weight of 245,000 lb; for takeoff at 244,200 lb at speeds up to 195 kts; and for landing at 180,000 lb up to 180 knots. To obtain the requisite strength without undue weight penalty, more of the "990" parts are made of very-high-heat-treat steels. There are changes in geometry and in components such as brakes, wheels, and tires.

This description, without pursuing the comparisons in detail, will take up the general structure, operation, and special characteristics of the "990" landing gears and associated systems.

OPERATION

Normal operation of the landing gear is by 3000-psi hydraulic pressure from the airplane's two hydraulic systems. The No. 1 system powers the nose landing gear, including door locks, brakes, steering, and the gear itself; the No. 2 system operates the main gears, doors, and brakes.

The landing gear control lever is on the right side of the center instrument panel. It has three positions: UP, NEUTRAL, and DOWN. In NEUTRAL, normal airborne position, hydraulic pressure is removed from the gear actuators at the selector and sequence valves. A solenoid-operated pin locks the control lever down when the airplane weight is on the struts, or when either main gear is not in proper position for retraction.

Gear and door position lights, beside the control lever, are off when the gear is fully retracted. Green lights illuminate to show gears down and locked; a red light comes on during transit, and remains on if gears are not all down and locked, or not up and locked, or when the gears are in any position not compatible with control lever setting. A door red light shows when gears are retracted with any door not closed and locked, or when gears are down and a main landing gear door is not locked. (The nose gear doors are not locked while the gear is extended.)

A warning horn sounds when the airplane is on the ground and the control lever is not locked in DOWN position; while airborne, it sounds if any power lever is retarded below 75% thrust and any gear is not down and locked.

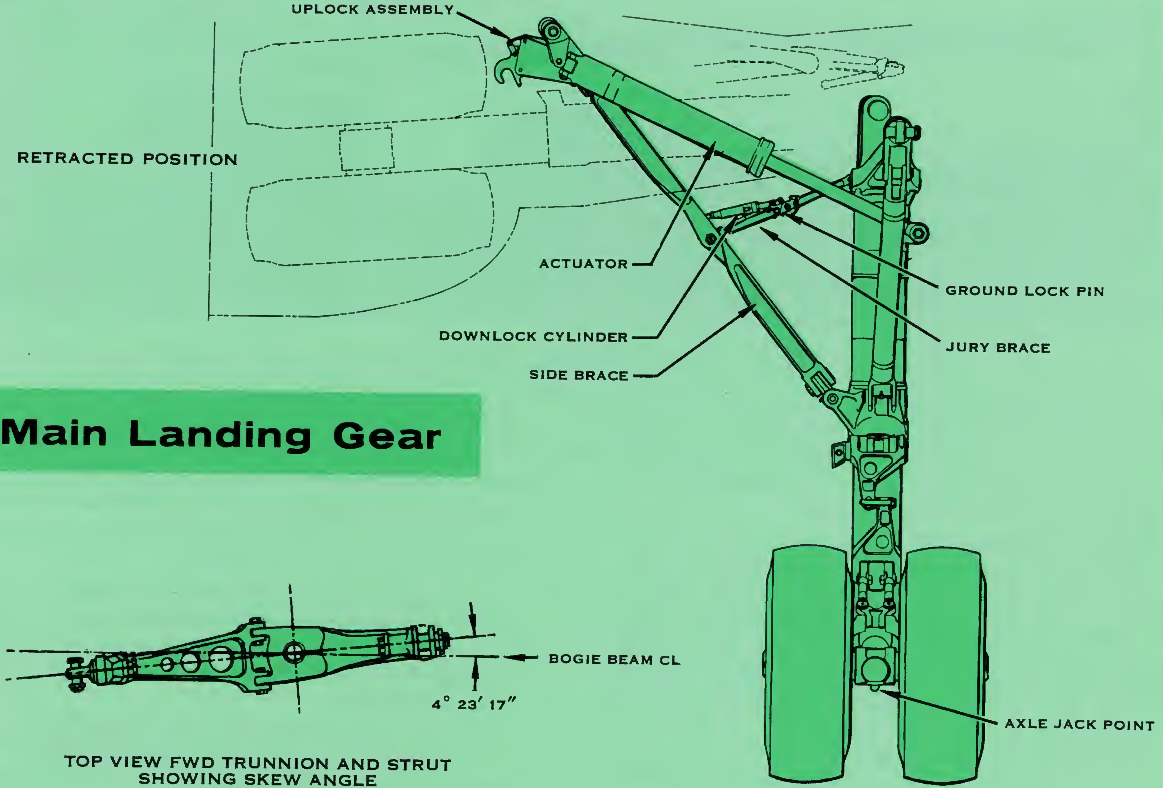
Emergency gear extension is by free fall, controlled by a lever on the aft face of the center pedestal. The lever is mechanically connected by a chain-and-cable system with the nose gear door uplocks and gear uplocks, and with the main gear door and gear uplatch. First motion of the emergency lever vents the landing gear hydraulic lines to return, and opens MLG door uplocks mechanically. Main gear doors are opened by pneumatic pressure, supplied from the 200-cubic-inch accumulator in the landing gear hydraulic system.

If No. 2 hydraulic system pressure fails, a check valve upstream of the accumulator isolates landing gear line pressure from the rest of the system. Even if hydraulic pressure is lost in landing gear lines, the accumulator will still have its precharge of 900 psi to open the main gear doors. Should the pneumatic pressure fail to operate properly, the weight of the gears will force the doors open and allow the gears to fall free. After emergency extension, the gear can be retracted in flight. Accumulator air will of course be lost and several cyclings may be necessary to bleed the lines. If any further emergency free-falls are necessary before charging the accumulator, the gear weight will open the doors and allow free-fall to the down-locked position.

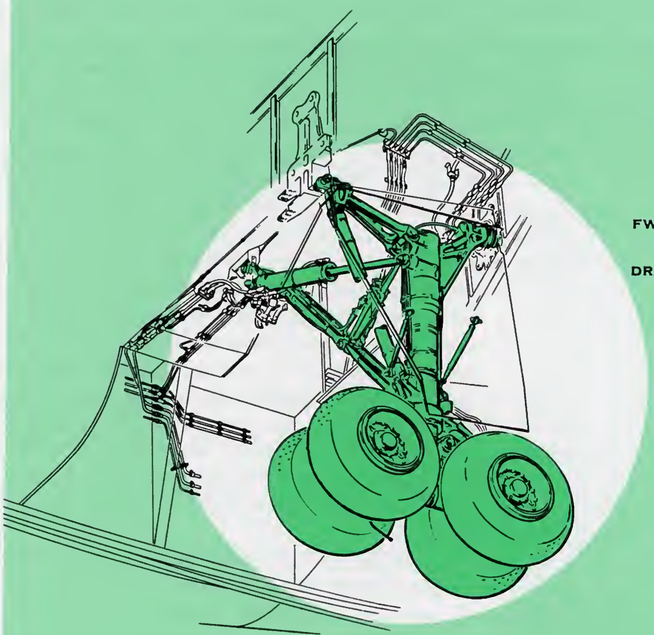
In the "990," both nose and main gears are designed for extension at speeds up to 320 kts IAS for speed braking.

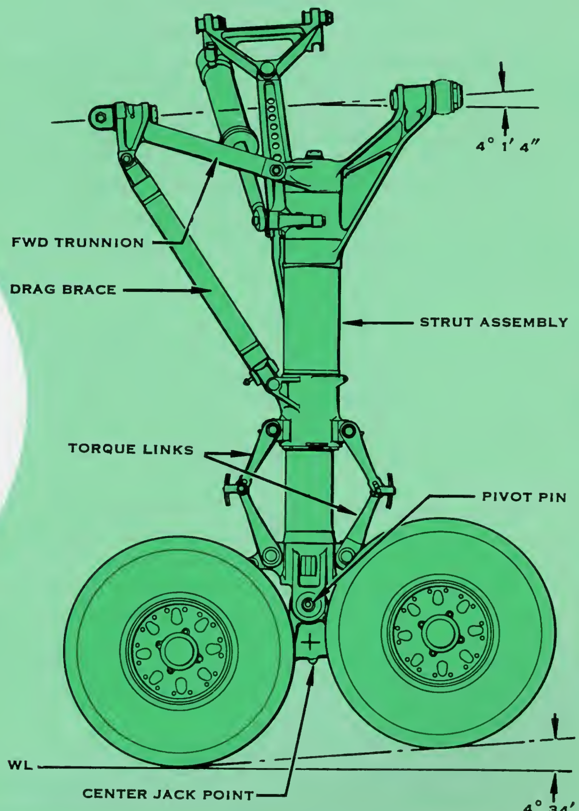
Brakes are operated by toe pressure on pedals linked by cables to brake metering valves. Emergency braking is applied to main gears only and is not controlled by the anti-skid system. Braking is pneumatic; pressure is supplied by an air flask mounted in the nose section, and controlled by a valve in the flight compartment.

Main Landing Gear



TOP VIEW FWD TRUNNION AND STRUT
SHOWING SKEW ANGLE





Parking brakes are set by depressing the brake pedals and pulling a parking brake handle, thereby locking the pedal control mechanism at the braked position. The brake accumulator will hold the brakes on for approximately an hour and a half, even though engines have been shut down and hydraulic system pressure is not available.

Nose wheel steering is controlled by a small wheel accessible to the pilot. Differential main wheel braking can be used for steering.

MAIN LANDING GEARS

Main landing gears have four-wheel trucks. Each truck is a tubular H-frame — a longitudinal "bogie" beam with axles at each end. Weight of the airplane rests near the center point of the bogie beam on a pivot pin, allowing the truck to rock longitudinally (around the lateral axis) through an arc of 33° 30′.

The yoke through which the pivot pin passes is the lower end of a conventional air-oil shock strut. Forward and aft torque links between strut piston and cylinder keep the truck aligned. With weight off the gear, an air-oil-spring truck positioner maintains the truck at 4° 34′ aft end up with respect to airplane waterline (in contrast to the "880" truck position, which is 4° forward end up).

When the airplane weight rests on the gears in normal ground attitude, the positioner puts a preload on the forward truck tires. The bogie beam pivot point is therefore 1/4 inch aft of the longitudinal midpoint, to equalize tire loading.

The main gear strut is 10 inches longer than that of the "880" and is attached lower in the wing structure, so that the airplane stands approximately 18″ higher at the main gears. Airplane waterline (and the cabin floor) normally slope 1° to 2° down toward the nose.

Basic frame pattern of the main gear is an inverted tripod, made up of the oleo strut cylinder, a forward drag strut, and an inboard side brace. The first two are load-bearing elements and are pin-mounted on the wing rear spar and the landing gear beam, which angles forward from the airplane centerline outboard to the inboard wing splice. Spar and beam are at the same relative position, with reference to the wing and fuselage spar boxes, as in the "880"; the landing gear center, however, is 11 inches aft of that of the "880." The oleo strut, therefore, instead of being 3 inches forward of the midpoint between spar and beam, as in the "880," is 8 inches aft of the midpoint.

The frame element attaching to the beam is an integral part of the strut cylinder. Forward, the spar attachment is to a trunnion from the top of the strut. The landing gear beam bears approximately twice as much of the airplane weight as does the wing spar. In consequence, the beam is considerably larger and stronger than in the "880."

The wheel well bears the same dimensional relation to wing spar and beam as in the "880." The gears, because they sit 11 inches farther aft, must therefore retract somewhat forward, rather than straight inboard. The pins on which the landing gear pivots during retraction are at an angle with the airplane centerline to allow the necessary "skew" in retracting.

The third leg of the basic tripod is the side brace, which braces the gear laterally on the ground, and folds as the gear retracts. Retraction is by a hydraulic cylinder, attached to the gear side brace structure, with its rod end attached to a fitting on the side of the oleo strut. A jury brace, between the knee of the side brace and the top of the strut, unfolds as the gear extends, and locks in the extended position to hold the side brace rigid on the ground. The downlock is a cam-and-roller mechanism in the jury brace knuckle, spring-locked in the down position and released by a hydraulic actuator. The main landing gear uplatch is a hook-and-roller type, normally locked and released by hydraulic actuator.

The main landing gear doors are hinged at the inboard side and open and close each time the gear is operated, whether raised or lowered. Mechanically-actuated sequence valves govern the gear and door hydraulic actuators. On the ground, the main gear doors can be opened and closed manually. A wing fairing, attached by links to the strut, and pivoted outboard of the trunnion, opens and closes with the gear.

High-strength steel (SAE 4340, heat-treated to 260,000-280,000 psi tensile strength) is used for the oleo strut cylinder, piston, bogie beam and pin, lower torque arms, and forward trunnion beam. Other steels used are AMS 6407, heat-treated to 220,000-240,000 psi; and SAE 4340, heat-treated to 200,000-220,000 psi. All sliding surfaces and moving joint pins are hard chrome-plated; other surfaces are chrome- or cadmium-plated. Aluminum alloys are 7178T and 7075T; drop forgings are 2014ST and 7079. All parts are interchangeable between right and left gears, except for the strut cylinders, which must be right- and left-hand parts, because of the skewed retraction.

NOSE LANDING GEAR

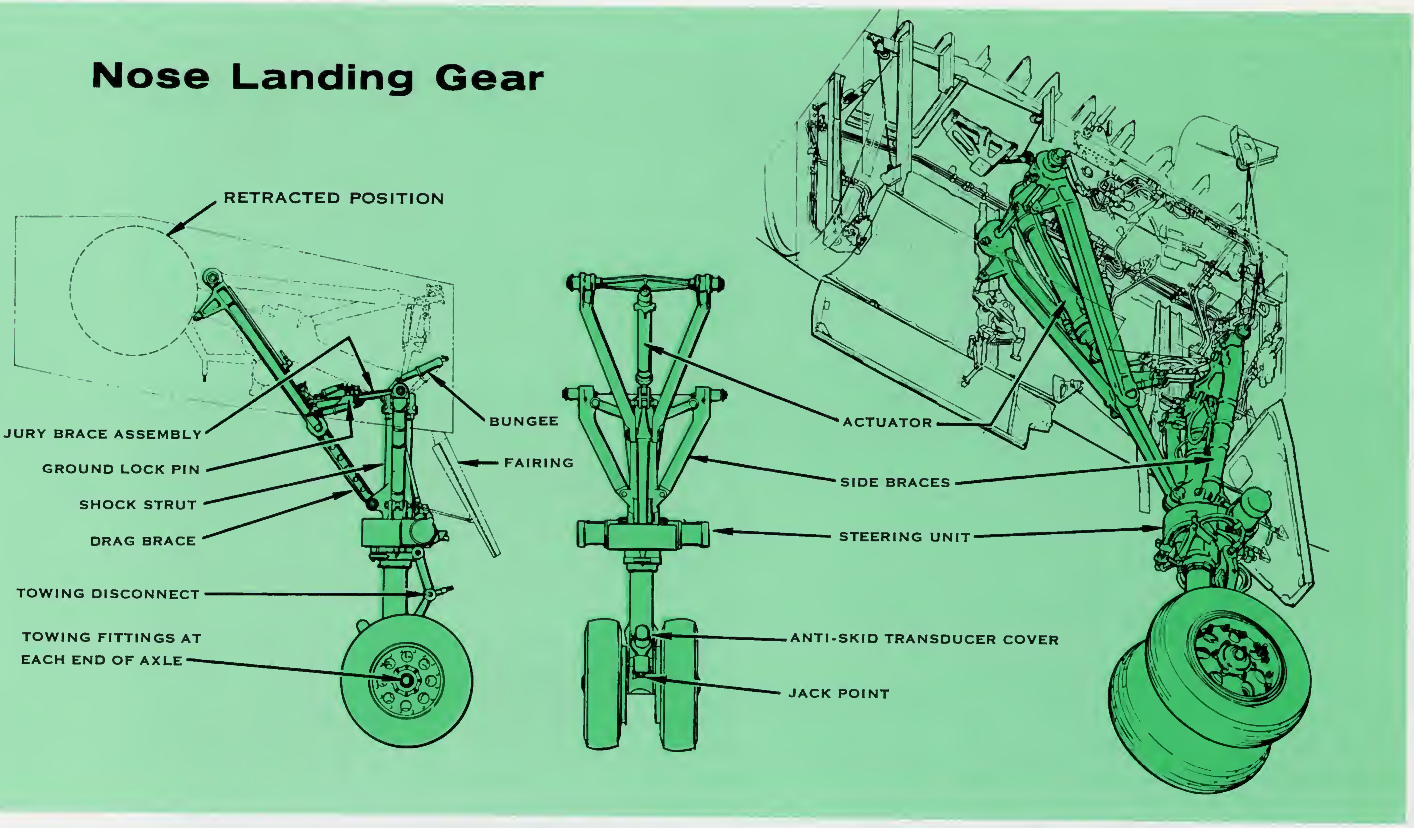
The nose gear strut assembly is about the same size and length as that of the "880," and is similar in many respects. Dual wheels are splined to a co-rotating axle; axle housings are integral with the shock strut piston. The nose gear load is carried on an inverted A-frame, made by side braces and trunnion bars attached to the strut cylinder and to the fuselage structure.

Retraction is forward. The lower drag brace, attached at the lower portion of the strut cylinder, joins an inverted A-frame consisting of the upper drag braces and a cross-beam. A jury brace attaches to the joint between upper and lower drag brace and to the top of the strut.

The hydraulic actuator is mounted at the center of the cross-beam between the prongs of the drag brace inverted A-frame. The rod end of the actuator attaches to a linkage assembly at the drag-brace-to-jury-brace joint; the actuator is approximately in line with the upper drag braces. The jury brace functions as both downlock and uplock.

Retraction and extension are as follows: When the gear is extended, the actuator is fully retracted, and the jury brace is locked in its in-line position by a cam-and-latch mechanism at the knuckle. The actuator

Nose Landing Gear



extends to retract the gear. First movement of the actuator rod end unlocks the jury brace; further movement "breaks" the jury brace, causing the drag brace to "break" also. As the jury brace folds, the drag brace also folds, pulling the gear up. By the time the jury brace is folded to its limit, the actuator force is being directed at an angle that continues to fold the drag brace, and the jury brace begins to straighten out. When the actuator is fully extended, the drag brace is completely folded, the gear is fully retracted, and the jury brace is again locked in line by the cam and latch, thereby locking the gear up.

Gear extension reverses the process: the jury brace unlocks, folds as the gear starts down, then straightens again to lock the gear open. Spring compression holds the jury brace locked; it is released by lever action of the linkages through lost motion of the gear. Uplock and downlock thus operate without hydraulic actuation.

There are two nose wheel well clamshell doors forward, and a fairing attached to and traveling with the gear. The clamshells are mechanically operated and are cycled closed by the last portion of gear extension. They can be opened manually on the ground. The clamshells, if left open on takeoff, will retract automatically when the gear is retracted.

Steering is by a rack-and-pinion drive, powered by dual hydraulic actuating cylinders. Steering range is 63° each side of center. Torque arms transmit the steering rotation to the wheel-and-axle assembly. Should hydraulic power fail, the wheels are free to caster. Removal of a quick-disconnect pin in the torque arm joint permits towing within normal turning radius; 360° rotation is possible by disconnecting hydraulic and electric quick disconnects. The towbar attaches to cups in the axle ends.

High-strength steel (260,000-280,000 psi tensile strength) is used for the "990" strut piston, forward jury brace link, brace bolt, drag brace pin, torque arm collar, and the steering rack, pinion, lug pinion, piston bearing and eccentric bolt.

WHEELS, BRAKES, ANTI-SKID

Wheels and brakes for the Convair 990 are supplied by Bendix. All wheels are split-rim, designed for tubeless tires. Each wheel has three fusible plugs to relieve tire pressure in event of excessive heat buildup in the wheel.

Nose gear tires are 29 x 7.7, 16-ply rating, Type VII; main gear tires are 41 x 15.0-18, 22-ply or 24-ply (depending on customer requirements), Type VIII. The type VIII tires have wider tread for the tire depth and are the best available design for handling heavy loads at high speeds.

Brakes are free-floating, multiple-disc, ceramic-metallic type, hydraulically operated. Nose brakes are automatically deactivated whenever the nose wheel is turned more than 7° ±1/2° from center.

Braking is monitored by an anti-skid system. Each main wheel brake and anti-skid mechanism operates independently. A transducer, mounted in the axle end, senses wheel velocity and deceleration, and causes the anti-skid control unit to release or apply pressure to the brakes as required.

Landing Gear Steels - Convair 880

A Convair 880 landing gear is as finely made and as precisely put together, scale for scale, as any watch. It must be. Comparatively light in weight, a main gear must bear a load of many tons, sometimes at speeds approaching 200 mph. It must handle this load during landing impact and under heavy braking, with additional margin for emergencies.

The strength to withstand such stresses, in a size and weight compatible with airplane use, is not bought cheaply, either in design or in materials. It took thousands of hours to define basic design requirements and more thousands to work out the mechanisms to meet the specifications. Where strength and fatigue resistance are needed, only the strongest toughest steels available today meet the requirements.

Many landing gear parts are still made of aluminum, or of steel processed to what is coming to be considered a low-heat-treat range — 180 ksi (180,000 pounds per square inch) or less tensile strength. But parts carrying major lateral and longitudinal stresses — nose gear side braces and lower drag brace, main gear drag braces and torque arms, are 220 to 240 ksi steels. So also are the nose gear strut cylinder and piston, nose and main gear axles, and many of the pins and bolts.

Two major assemblies, the main gear oleo strut and the axle beam, are of still higher heat-treat level. Nine-tenths of the airplane weight rests on the main gears. More specifically, it is concentrated at the struts; with the airplane fully loaded, more than 40 tons rest on each strut, which in turn rests on the approximate center of a single longitudinal tubular beam (the "bogie beam"), at the ends of which are the axles. To bear this concentrated load, strut cylinders, pistons, and the bogie beams are of chrome-molybdenum-nickel steel, heat-treated to 260 to 280 ksi. A few pins and bolts in both main and nose gears are of this high-heat-treat level.

The 220/240-ksi steels are AMS 6407 (a low alloy steel) or AMS 6427 (SAE 4330 modified). For heat treat to the 260/280-ksi range, the steel is SAE 4340, an electric-furnace fine-grain steel of aircraft grade.

For practical purposes, these steels may be said to be processed to just about their ultimate capability for strength and toughness. They are very hard; a blow with an ordinary ball peen hammer probably would not dent the bogie beam. The hardness goes with the strength, along with a necessary accompaniment of some brittleness. AMS 6407 and 6427 steels, after hardening, are heated to only 500° to 600° F for tempering; the 260/280-ksi steels may be tempered at only 400° F — approximately the drawing temperature for a cold chisel.

Although the alloy content increases toughness and "hardenability" (capacity for hardening to depth when quenched), it is not possible to obtain the requisite strength without sacrificing ductility. High-heat-treat steels will withstand an almost incredible static load, and even severe impact without failure — but not necessarily without damage.

This fact is being recognized by airlines operating heavy jet transports. In the test program and in service to date, the "880" landing gear has had a very good record. This is because of the background of structural analysis during design; every pin and bolt, every juncture where parts are mated, was subjected to meticulous stress analysis and the detail design tailored to the requirement. The "880" record will continue to be good; but it is more dependent than ever before on careful maintenance and inspection.

An example is a main gear truck found to have a slight dent in the bogie beam, apparently caused by jacking the front axle too high in an effort to get a jack under the center jack point with both rear tires flat. The excessive truck angle caused the yoke at the bottom of the strut piston to contact the beam. Thorough inspection showed no external crack, nor any sign of internal damage that could be seen without removing the beam, and the airplane was flown some days without mishap. But, when the beam was removed for better inspection, it turned out to have an internal surface crack under the dent that, sooner or later, might have caused failure.

In Convair testing, it has been found that damage to hard steel may occur from impact or high local stress concentrations that leave no visible dent. There is only one safe rule to follow: whenever there is any visible indication of high stress or impact, or whenever it is known that a gear part has been subjected to heavy impact or localized stress, the part, whatever its appearance, should be removed and thoroughly inspected by all the methods at hand.

Penetrant inspection is useful for bare or chrome plated parts, particularly if the part can be inspected under stress. But, dye penetrant inspection is not enough today. A cadmium coating is ductile, and may remain unbroken even though the surface of the steel has sustained fracture. X-ray is useful chiefly to verify findings from other methods. Only magnetic particle inspection, with both longitudinal and transverse polarization, and ultrasonic inspection — and preferably both — can put the final OK on steel of such critical quality.

High-heat-treat makes steels more notch sensitive — more likely to develop cracks from scratches, nicks, or abrasions, even though not caused by impact. When within relief limits, such marks should be filed out by hand, and the area shotpeened.

Overhaul practices are equally critical in importance. Most operators have become familiar with baking and shot-peening in reworking landing gear parts. The extent to which both processes are required, however, is unprecedented. High-heat-treat steels, for example, must be baked at 280° to 400°F for 8 hours before any rework; for another 8 hours after plate stripping; and for 8 hours again after machining or grinding before plating. Within an hour after plating with either chrome or cadmium, they must be baked 23 hours at 280° to 400° for embrittlement relief. If

retempered and not replaced during rework, they require a 24-hour bake at 250° for austenite stabilization as the last thermal treatment.

In brief explanation of the reasons for these process steps, the low-temperature baking for long periods serves to relieve minor stresses built up by loading, machining, or heat treat, and also to remove hydrogen. Hydrogen embrittlement, a phenomenon to which much attention has been devoted since heat treats were extended to the current ranges, results from introduction of hydrogen into the steel, usually by reaction with acids. Peening with small shot sets up surface compression stresses that add materially to fatigue life. Metallurgists are not in entire agreement on just why hydrogen dissolves into and embrittles steel under certain circumstances, or why peening helps before chrome plating, but the effects are well established empirically.

Because of hydrogen embrittlement, the acid stripping of plate, and the pickling and electrolytic cleaning of high-heat-treat steels are prohibited. Parts must be stripped by reverse current completely before replating; "plate over plate" prevents hydrogen escaping in the after-plating bake.

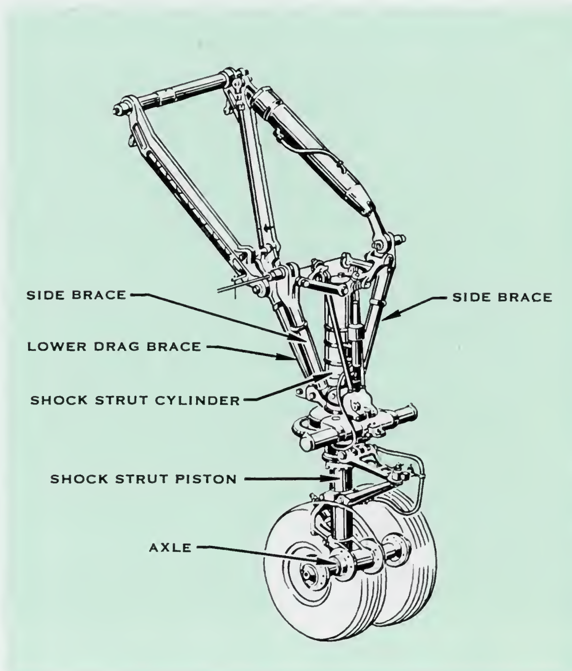
In baking, hardening, and tempering, temperature control is especially critical. It has been noted that SAE 4340 steel is tempered at 400° to 500°F. Obviously, baking temperatures higher than 400° will affect part strength; on the other hand, baking at less than approximately 375° is of limited usefulness. Decarburizing — loss of carbon from heating — is similarly of critical importance. Oven atmosphere control is necessary in any heating of 260/280-ksi steel to 700°F or more. Heating a hardened part by torch is not permissible; the heat must be rigidly controlled. Two tempers are required for all steels heat-treated to 220-ksi and above.

Grinding of hardened parts must be done with extreme care with never more than the specified amount removed per pass on outside and inside diameters. Unless the grind is only for finish of chrome plate, it must always be followed by shot-peening.

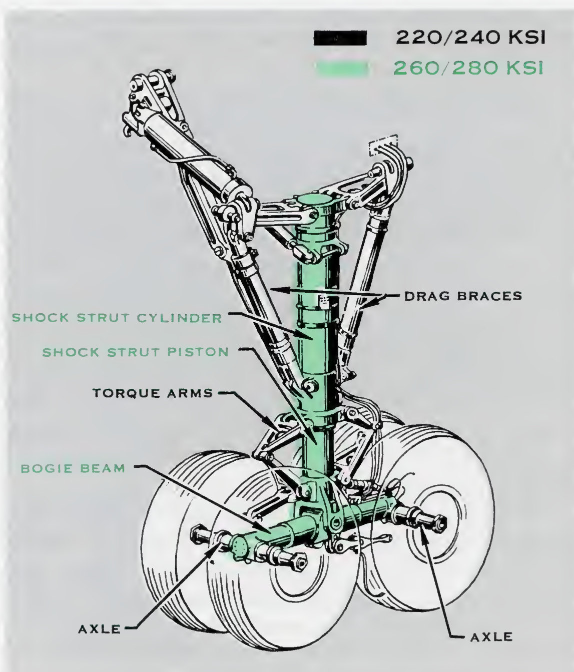
Straightening can be done after normalizing and then process-annealing the part. After hardening, the 220/240-ksi steels may be straightened under low heat; but 260/280-ksi steels can be straightened only to a limit of 1/4° overall length and at temperatures under 200°F, followed by a third 4-hour temper at 400°F.

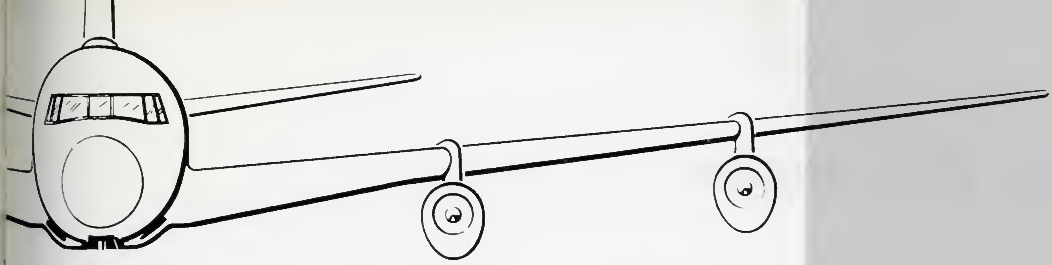
This summary sketches, generally, most of the principal requirements and restrictions peculiar to processing high-heat-treat steels. In the "880" Overhaul Manual, a complete chapter is devoted to specific instructions on rework of steel landing gear parts. This is backed up by research conducted by Convair and Cleveland Pneumatic Tool Company, manufacturer of the landing gear, on the general characteristics of the steel and on actual landing gear parts. At Convair, extensive testing has been done on inspection methods. Parts were literally beaten to pieces with heavy sledge hammers, to find out what the gear would take, how damage begins, and how it may be detected.

The results are available in the maintenance and overhaul manuals. Some extra care in day-to-day maintenance and inspection and close adherence to the processing requirements during overhaul will pay in long service life and safe operation of Convair jet airliners.



All parts called out in nose gear (above) and main gear (below) are of steels processed to 220,000 psi, or more, tensile strength; nose steering collar and some pins are not shown.



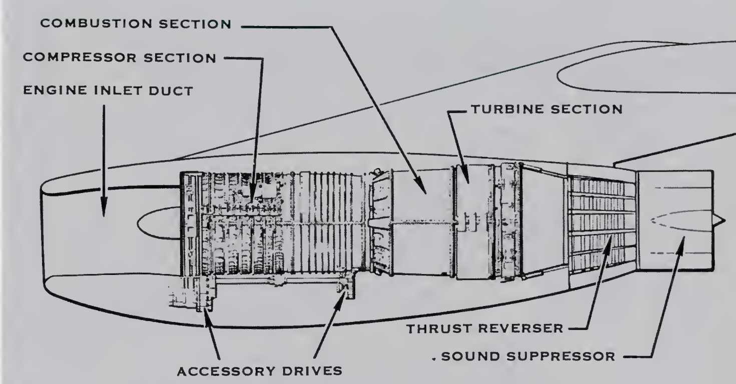


CONVAIR "880" AND "990" POWER PLANTS

Convair's "880" and "990" jet transports are powered by four General Electric CJ805 engines, installed in pods suspended on pylons below the wings. The "880M" engine is the CJ805-3B turbojet; the "990" has the CJ805-23 aft fan. The two versions are similar in the compressor, combustion, and turbine sections — approximately the forward two-thirds of the engine. The "880" engine exhaust section consists of thrust reverser and sound suppressor; the "990" has a fan aft of the turbine section, with a target-type thrust reverser aft of the fan.

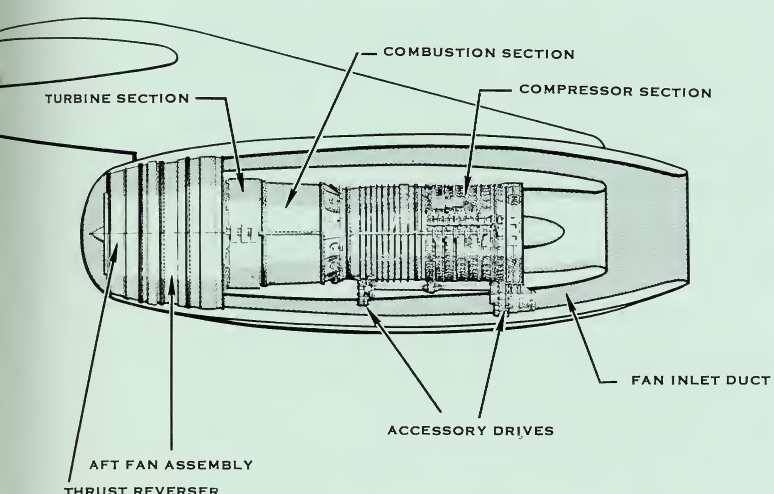
The CJ805 is a single-spool axial-flow high-pressure-ratio engine, characterized by unusual simplicity of design, extremely low weight, low specific fuel consumption, and maximum accessibility for servicing and maintenance.

The aft fan, newest modification of the jet engine principle, represents another solution to the problem of combining the best elements of propeller and jet propulsion. Propellers are most effective in dense air and at low speeds.



"880" ENGINE INSTALLATION

"990" ENGINE INSTALLATION

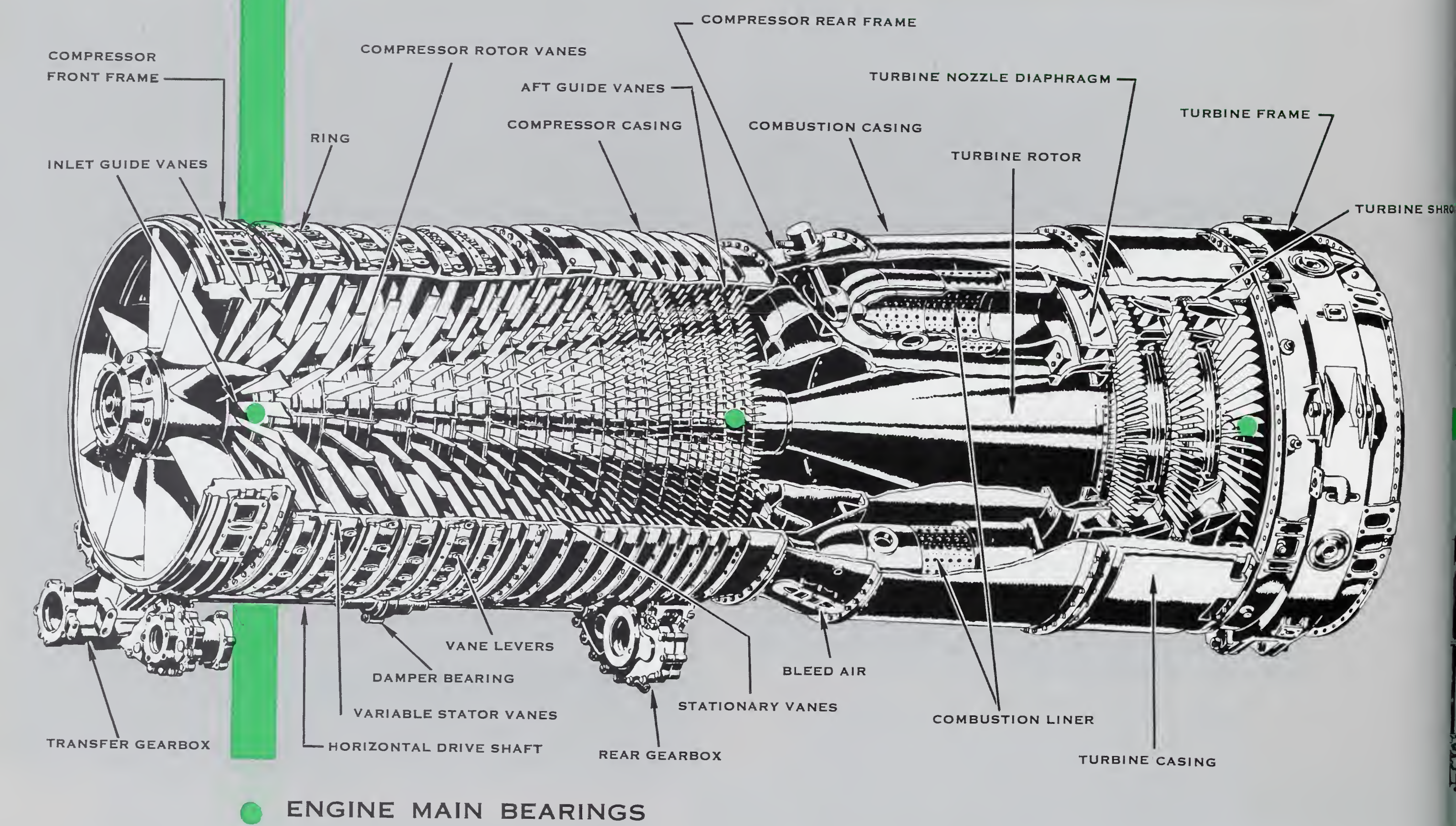


The aft fan is a turbine-driven fan. The turbine, in the CJ805-23 engine, is driven by exhaust gases at comparatively high speed. Outside the turbine blade radius, extending outside the engine combustion section, are fan blades that are extensions of the turbine blades. This fan drives aft a greatly increased volume of air, at somewhat slower speed than the jet blast, but in sufficient volume to add to the engine's thrust.

Since the "880" and "990" engines are identical in the forward portion, the description of the engine components herein applies to both versions, except where specifically noted as applicable to one or the other.

The main sections of the -3B engine are: 1) a 17-stage axial compressor, in which the inlet guide vanes and first six stages of stators are variable; 2) a cannular combustion section with ten combustion liners, and inner and outer casings; 3) a three-stage turbine; and 4) an exhaust section, including thrust reverser and sound suppressor. The forward portion of the -23 engine is the same; a redesigned turbine frame, an aft fan housing, and target type thrust reverser complete the -23 engine.

STRUCTURE OF CJ805 BASIC ENGINE



Total weight of the -3B engine, including all accessories, ducts, thrust reverser and sound suppressor is approximately 3500 pounds. Weight of the -23 engine and reverser is approximately 4325 pounds. This light weight was obtained by use of a load-carrying outer skin, conical construction of support members, and weldment type construction. Also, the single-spool compressor requires fewer bearings and support structures than have been necessary with other designs.

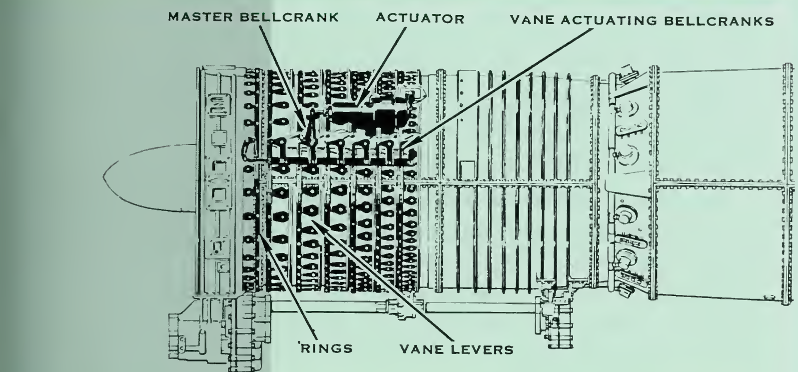
Variable stators allow a high-mass flow of air with a comparatively small diameter compressor and small frontal area. This has made possible an aerodynamically clean engine pod. The compressor is designed for optimum performance at cruise speed and above.

The compressor front frame, the forward structural member of the engine, is a machined magnesium casting consisting of an outer shell connected to an inner hub by eight streamlined hollow struts, equally spaced. The hub houses the forward bearing of the compressor and a gearbox for the accessory drive. The accessory drive transfer gearbox is mounted on a pad at the bottom of the vertical strut. The transfer gear box is driven by a vertical drive shaft through the strut. Lubrication and anti-icing air lines run through the struts to the hub.

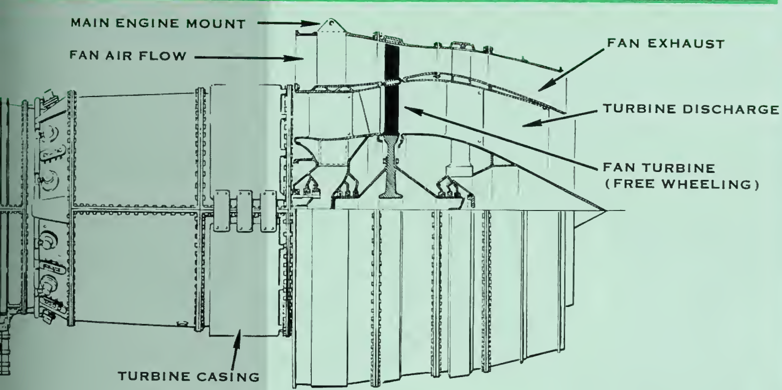
Aft of the struts are 20 sets of stators, 7 of which are variable, so as to afford a variable incidence for inlet air.

The compressor stator case is vertically divided between the 7th and 8th stages, and split and bolted together at the horizontal center line. The vanes in each of the six rows are connected by levers to rings that move circumferentially around the outer skin, moved by sets of bellcranks, one set on each side of the engine. The bellcranks on each side are interconnected by a master rod to assure vane synchronization. The second bellcrank on each side is a master bellcrank and is connected to a hydraulic actuator.

DETAIL OF VARIABLE STATOR LINKAGE



DETAIL OF AFT FAN AND THRUST REVERSER



The four sections of the compressor stator case are removable for internal inspection; however, since they are load-carrying elements, only one section may be removed at a time without disassembling the engine.

The compressor rotor consists of a series of 17 stages of blades, discs, and spacers, bolted in sections. Stub shafts at each end of the spool are internally splined to receive, at the forward end, the engine forward gear case horizontal shaft and, at the aft end, the forward end of the turbine shaft.

The compressor rear frame is the mid-structural member of the engine. It is a sheet steel weldment, consisting of an outer shell and inner diffuser section, with ten equally-spaced struts supporting the center main bearing. This is a thrust ball bearing and transmits to the rear frame the axial loads from the compressor as well as radial loads imposed by the rotating parts.

Two manifolds on the inner surface of the diffuser collect compressor discharge air and route it to the surface through struts Nos. 2, 4, 7, and 9. The bleed air manifold is attached to pads on the outer shell at the ends of these struts.

The compressor rear frame has brackets inside the outer shell for attaching the forward ends of the ten combustion liners, and is also the mounting for the fuel ring and nozzles. The combustion liners are mounted in a concentric annulus between inner and outer combustion casings. Either half of the outer casing may be removed for inspection of the liners.

Each combustion liner is a double-walled sheet steel cylinder, with the inner liner ceramic-coated. A fuel nozzle is inserted into a self-aligning eyelet in the forward end of each liner, and all liners are interconnected by cross-ignition ducts.

The inner shroud of the first stage turbine nozzle diaphragm is bolted to the rear flange of the inner combustion case. Second and third stage nozzle diaphragms are in a stator assembly consisting of a turbine casing, which is split along the horizontal center line, the two nozzle diaphragms, interstage air seals, and two turbine shrouds.

Second and third stage nozzles, and the honeycomb turbine shrouds, slip into grooves on the inner surface of each half of the casing, and are secured by pin bolts. Interstage air seals, while part of the stator assembly, are not split into halves, but are assembled with the turbine rotor and secured by a pin and slot arrangement to the inner band of the turbine nozzles. A turbine bucket containment ring, split in halves along the centerline and bolted together, surrounds the stator casing.

The turbine frame is the aft structural member of the engine. It is a sheet steel weldment, with an outer shell and an inner hub that contains the third main bearing, and serves as a diffuser for exhaust gases. Seven radial struts connect outer shell and hub.

In the -23 engine, the aft turbine fan is attached to the rear of the turbine frame. In this, the fan is a single unit, turning freely on its own bearings. Since it is not connected to the other rotors in any way, it has little effect on engine starting torque or operation at idle speeds.

AIR-FLOW SYSTEM

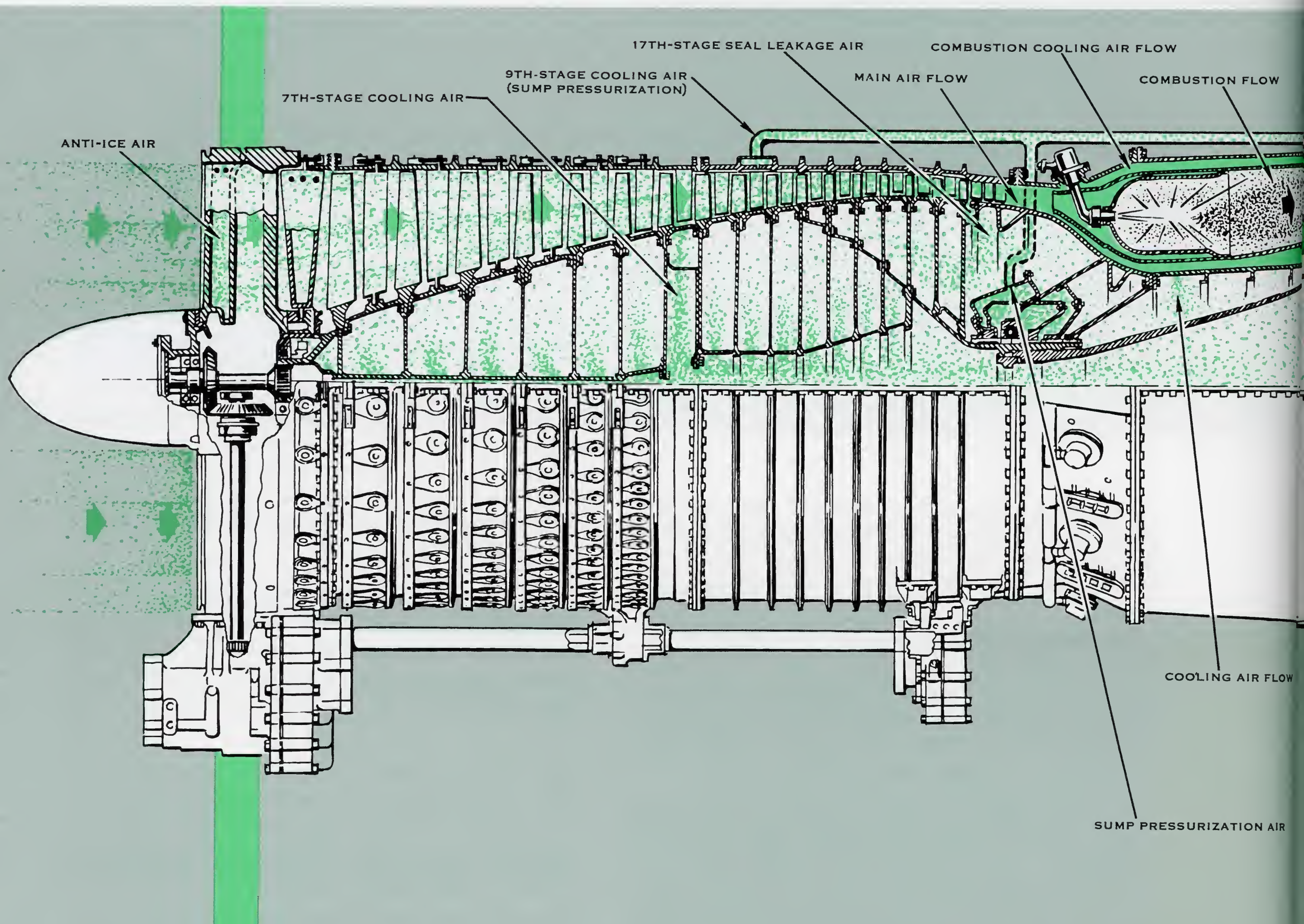
The major part of the 17th-stage compressor discharge air supply is used for supporting combustion and for cooling the combustion components by keeping air flowing over their surfaces. A portion of the supply is bled off through the compressor rear frame struts to operate cabin air conditioning and pressurization equipment and for wing anti-icing. The 17th-stage air is also used for direct cooling of first and second stage turbine nozzles, the first stage turbine rotor shroud, the mounting bases of the first and second stage turbine blades, and for engine anti-icing.

Engine anti-icing flow is bled through a port in the outer diffuser wall and ducted forward to the compressor front frame struts.

Air temperature at the 17th stage is approximately 730°F at takeoff power, sea level static conditions. Cooler air than this, under less pressure, is collected at the 7th and 9th stages for cooling the rotor and pressurizing the bearing sumps.

Air is bled inward through holes around the 7th-stage torque ring into ducting in the center of the rotor. Bleed holes allow the air to pressurize the discs between the vane stages, thus adding strength by reducing the pressure differential across the discs. Aft, air flows through the center of the stub shaft and turbine rotor shaft, and is directed against the fore and aft faces of the turbine discs and the inner surface of the torque rings.

An external manifold collects air on the upper half of the compressor rear casing at the 9th stage. This air is ducted through the struts of the compressor rear frame, and of the turbine frame, into jackets surrounding the center and after bearing sumps, pressurizing the carbon seals. Leakage past the seals aids in sump pressurization.

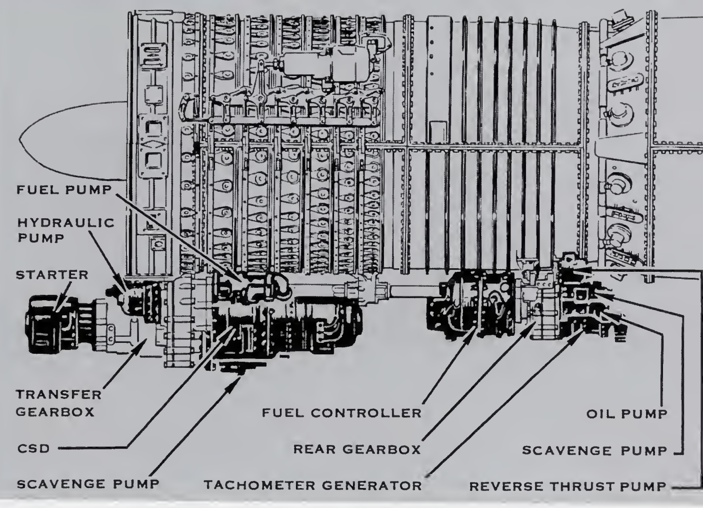


AIR FLOW SCHEMATIC

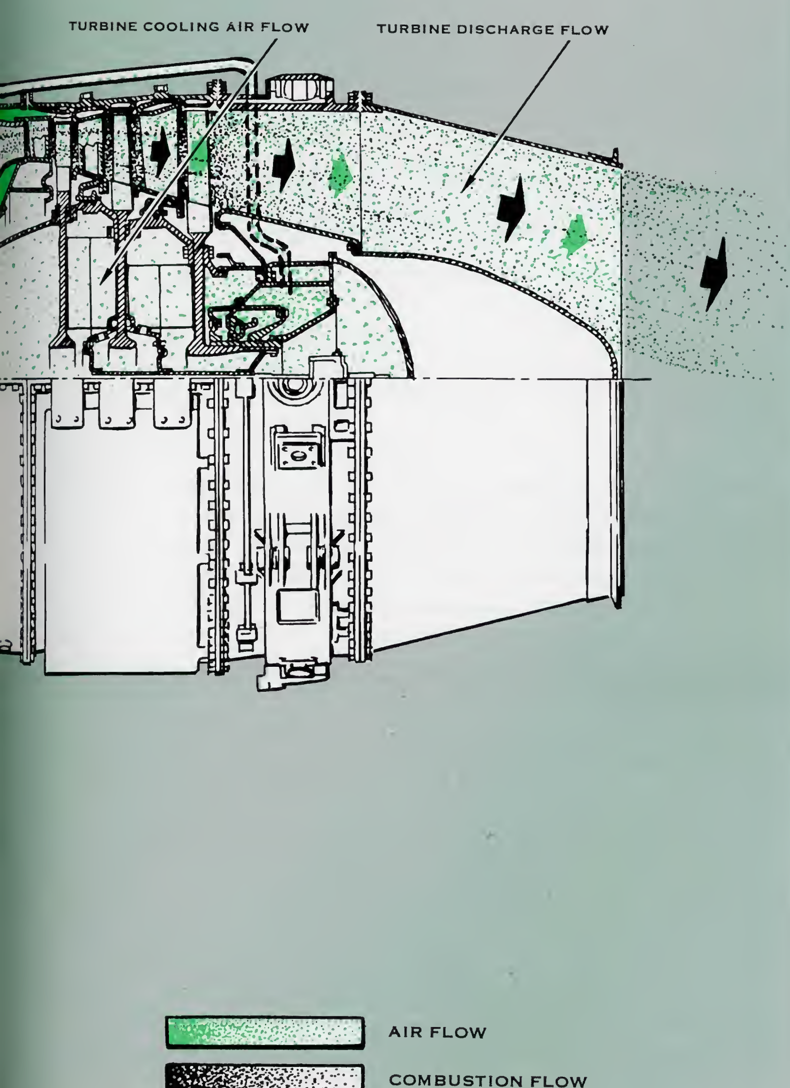
ACCESSORY DRIVES

A vertical shaft through the compressor front frame lower strut, geared to the compressor stub shaft, drives two gearboxes mounted beneath the engine, one a transfer gearbox mounted at the end of the strut on the compressor front frame, and the other mounted on the rear half of the compressor casing. A horizontal shaft runs from the transfer gearbox to the rear gearbox, through a damper midway between the gearboxes.

Both gearboxes have power takeoffs on forward and aft faces. The starter is mounted on the transfer gearbox forward face. Beside the starter is a mounting for the hydraulic pump. The fuel pump, constant-speed drive and generator, and a scavenge oil pump are on the aft face of the gearbox.



The main fuel control is mounted on the forward face of the rear gearbox. On the aft face is a hydraulic pump for reverse thrust actuation; main oil pump; tachometer generator; electrical load switch; and a scavenge oil pump.

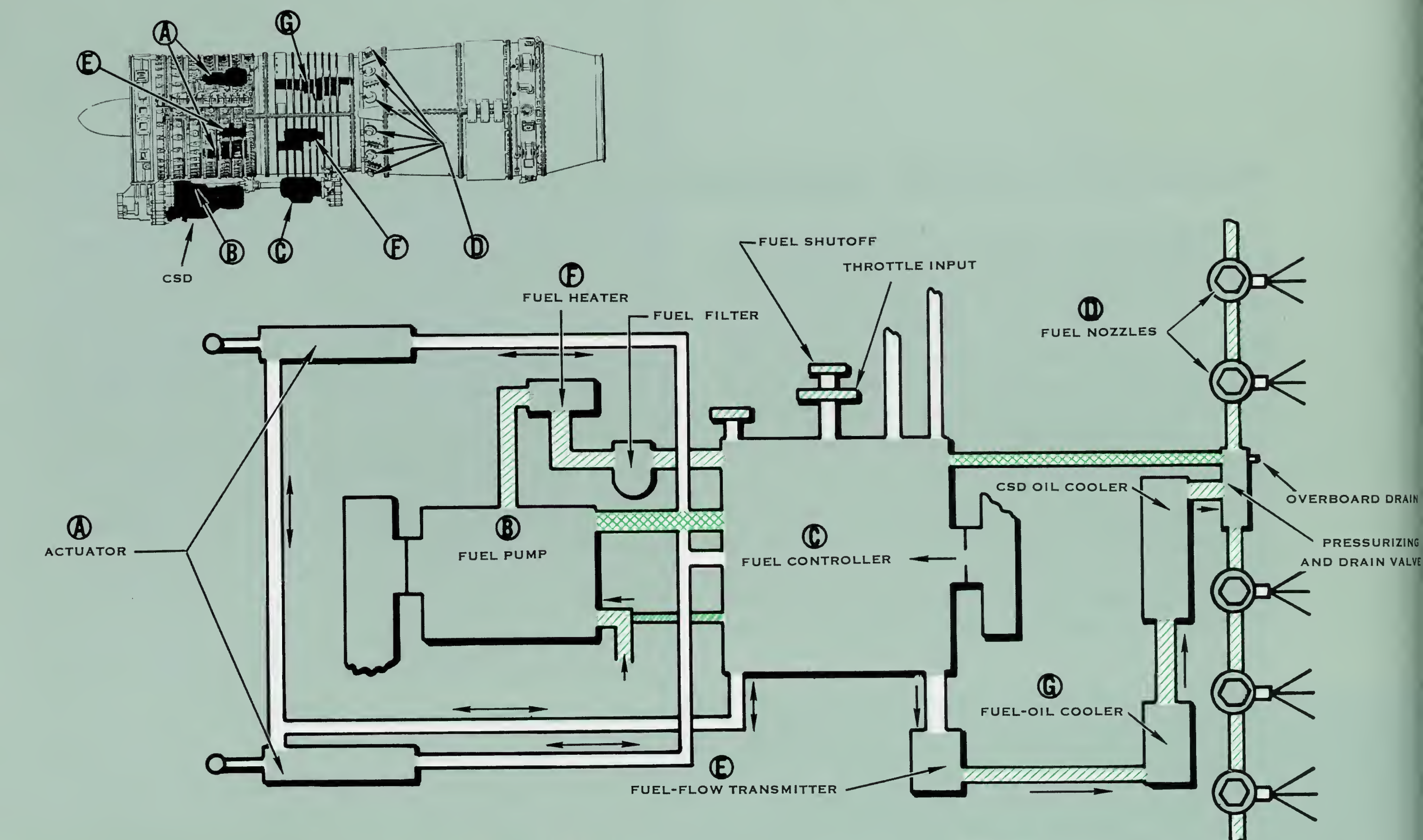


FUEL SYSTEM

Besides scheduling fuel quantity necessary for operating the engine from start to maximum takeoff power, the CJ805 fuel system provides for use of pump discharge fuel for hydraulic operation of the variable stator actuators, and metered fuel as coolant for engine lubricating and constant-speed drive (CSD) oil.

The fuel boost pumps in the wings deliver fuel to the engine at low pressure. In the engine fuel pump, a centrifugal boost element raises pressure, and two gear-type positive-displacement elements further increase the pressure to operating level, depending on flow requirements. The elements are separate, and incorporate a shear section between them. In event of failure of one element, the other element will supply sufficient fuel for all normal aircraft operation.

From the pump, the fuel is routed to the fuel control through a 40-micron filter and a heater. The fuel control is a hydro-mechanical metering device that performs the following functions: 1) provides engine speed control, 2) schedules variable stator vane angle to control air flow into the engine, 3) provides surge



FUEL SYSTEM SCHEMATIC

protection, 4) limits turbine inlet temperature, and 5) provides a positive fuel shutoff. To perform all these tasks, the fuel control is necessarily complex in design, and a detailed description is beyond the scope of this article.

To meter fuel, the compressor inlet temperature, compressor discharge pressure, engine speed, and pilot's power lever setting are used as parameters. The metered flow is passed through engine and CSD oil coolers enroute to the fuel nozzles.

From the oil coolers, the fuel is routed to the nozzles through a pressurizing and drain valve. This valve has two functions: 1) it prevents fuel-flow to the nozzles until pressure in the fuel control is sufficient to operate the servo assemblies, which compute the fuel quantity and variable-stator schedules; and, 2) it vents the fuel in the manifold into a collector can after shutdown to prevent nozzle coking and post-shutdown fires.

The nozzle in each combustion liner is a duplex type. At low pressures, fuel passes through a small drilled passage in the stem; as pressure rises, a flow divider valve opens and allows fuel to pass through a larger passage. Entry ports to the mixing chamber are tangential to the chamber walls, so that the fuel spray is given a spinning action.

Since fuel flow is often greater than that required for oil cooling, some fuel may bypass the coolers. The engine fuel can absorb all the heat from engine scavenge oil during normal operation. A thermostatic control bypasses sufficient oil to prevent fuel temperature from exceeding operating limits.

The fuel controller also directs unmetered fuel flow at pump discharge pressure to the compressor variable stator actuators. These are single-ended hydraulic cylinders, in which the piston is driven in either direction by fuel pressure. The piston has a bleed orifice so that a constant flow of fuel will cool the actuators.

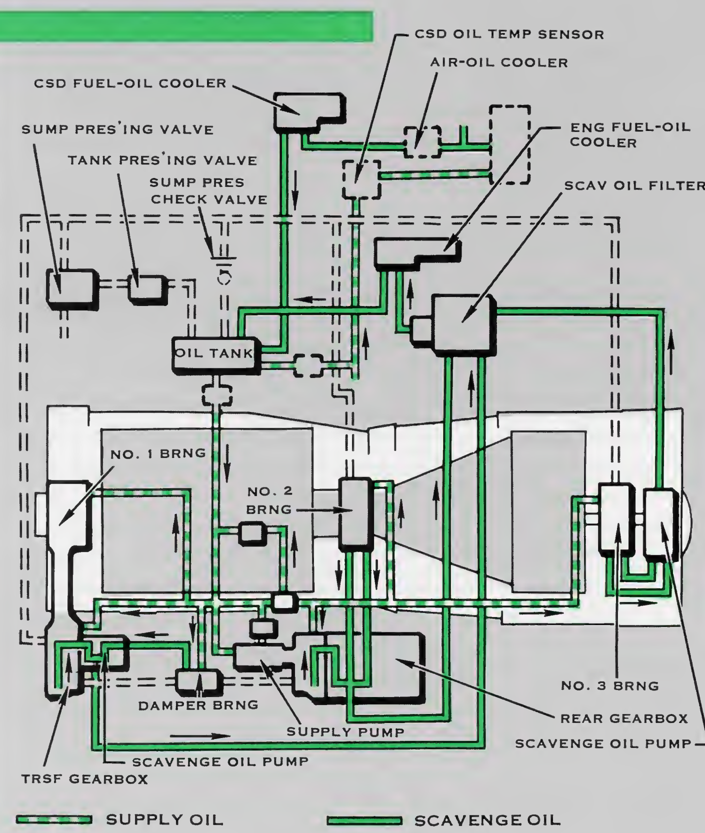
Two field adjustments are provided on the fuel controller, one for idle rpm, one for maximum rpm. The CJ805 is designed to afford maximum thrust on either JP-4 or kerosene fuels.

LUBRICATION

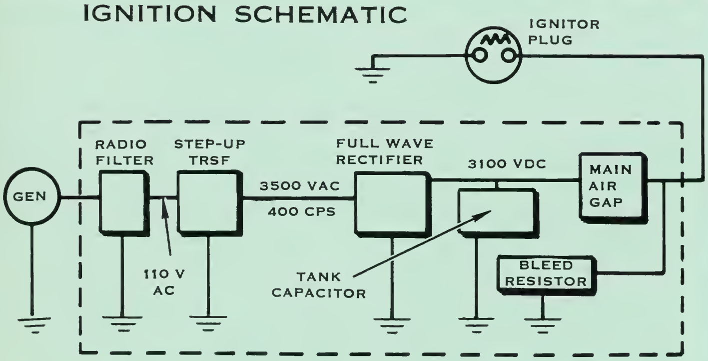
The lubricating oil supply tank is mounted on the right-hand forward compressor casing. MIL-L-7808C oil is used for lubrication. A vertical bulkhead divides the oil tank into two sections: one for engine oil and the other for the hydraulic oil that powers the CSD unit and operates the thrust reverser. Sufficient oil capacity is provided in the engine oil and CSD tanks for operation well beyond maximum range.

Near the top of the tanks are screened gravity fill ports with dipsticks attached to the filter caps.

Oil flows from the engine compartment of the tank to the lube supply pump; thence, through filters to three main bearings in the Convair 880 (five bearings in the Convair 990) and to transfer and rear accessory drive gearboxes. Scavenge pumps in the bearing sumps, gearboxes, and CSD unit return the oil through filters, air and fuel-oil coolers, and de-aerators to the tanks. A sump pressurizing system, utilizing bleed air across the bearing seals into the sumps, regulates pressure in the tank, gearboxes, and sumps.



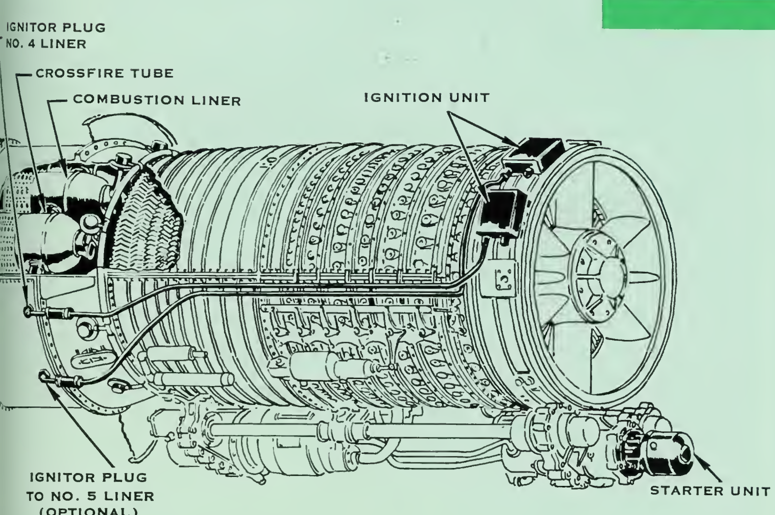
IGNITION SCHEMATIC



The sumps and gearboxes are manifolded and vented into the upper air-expansion space in the engine compartment. A tank pressurizing valve maintains a tank pressure above ambient pressure.

A pressure relief circuit protects instrumentation from excessive pressures in cold weather starts.

IGNITION AND STARTING



The starter is an AiResearch air turbine motor, mounted on the front pad of the forward accessory drive gearbox. It may be actuated either by a ground supply unit or by bleed air from other engines. Starting time is approximately 40 seconds. The starter cuts out automatically at 3500 rpm.

An arc from the ignitor plug ignites fuel in the No. 4 combustion liner. This flame spreads through crossfire tubes to the remaining combustion liners. An additional ignitor is installed on the No. 5 combustion liner.

The ignition circuit uses 110-volt, 400-cycle ac, stepped up by transformer to 3500 vac, and then rectified to dc. This is fed to a relatively large capacitor which discharges approximately four times a second, providing an intermittent high-temperature arc across the ignitor plug.

ENGINE CONTROLS

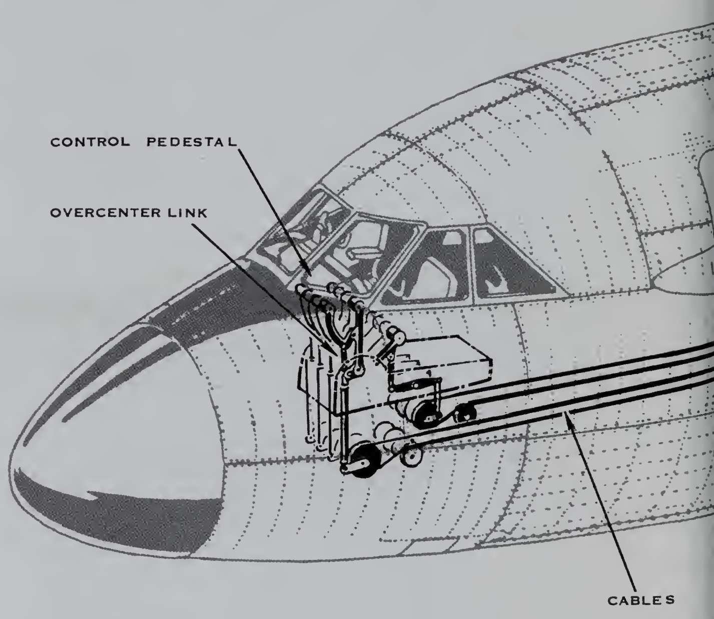
The two principal pilot controls for each engine are the power lever and reverse thrust lever assembly, and the engine start and fuel shutoff lever. These are mounted on the pedestal so as to be accessible to pilot and copilot. The power and fuel controls operate rods and cranks to a closed cable system below the flight compartment floor. The cables run to torque boxes in the pylons, from which teleflex push-pull cables transmit rotation to torque boxes on the engine fuel control. An automatic tension regulator at the wing front spar centerline maintains cable tension at 30 ± 15 pounds to all engine controls.

The fuel shutoff lever has two detent positions, OFF and RUN. When the lever is moved from OFF to RUN, it opens the fuel shutoff valve. After the engine reaches 3500 rpm, the starter automatically cuts off ignition. Returning the lever from RUN to OFF cuts off fuel to the engine.

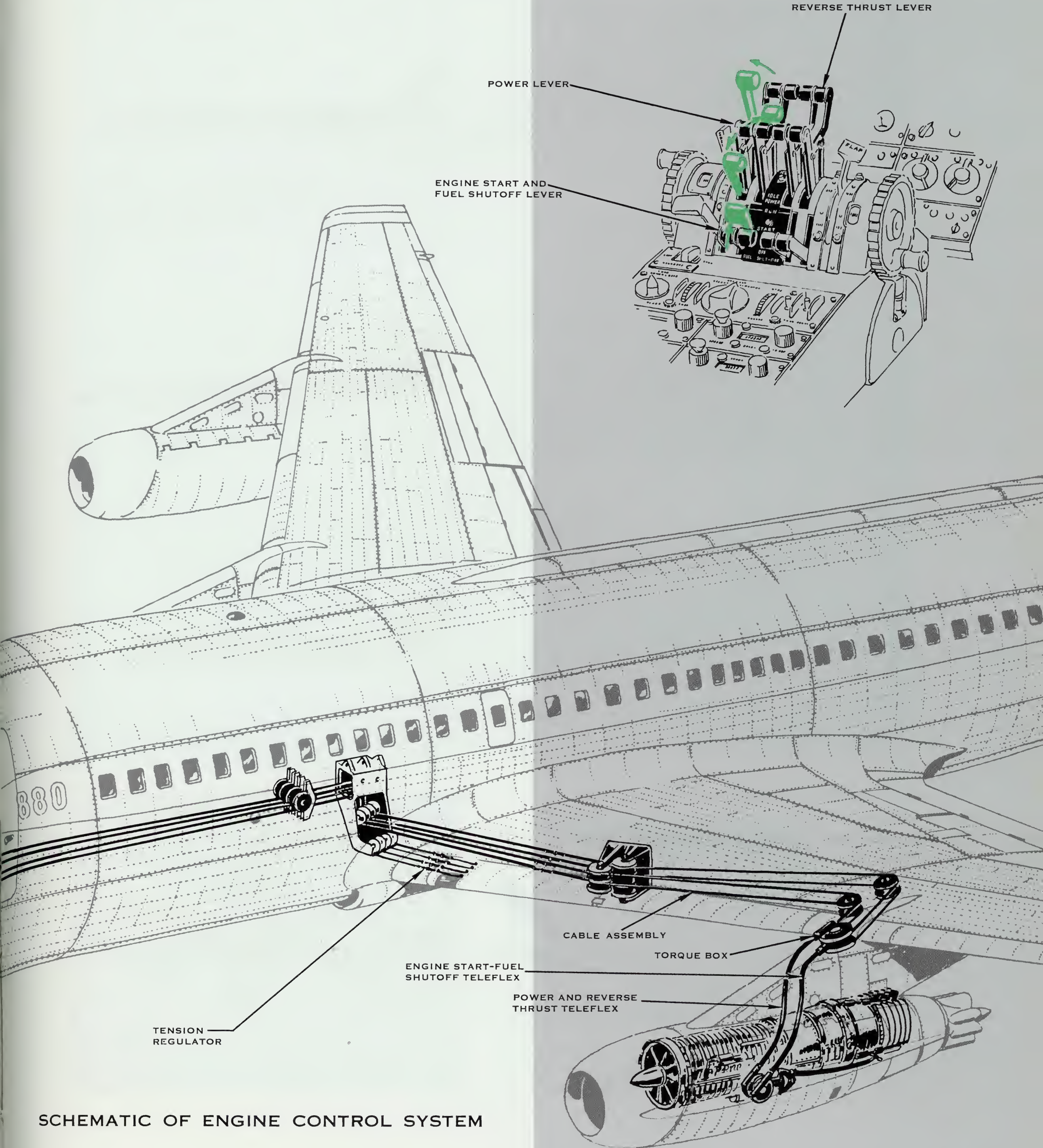
The power lever moves forward from idle rigged position. At extreme forward position, takeoff rpm is available.

To rotate the cable quadrant, the power lever operates a push-pull tube and bellcrank assembly. The first element of the push-pull linkage is one half of an L-shaped lever, the thrust reverse control lever (see schematic). When the power lever is pushed forward, the thrust reverse lever is locked in place by an overcenter link so that it is a rigid part of the power control linkage. When the power lever is pulled back to idle position, the overcenter link becomes a fixed tension link. The thrust reverse (L-shaped) lever can then be pulled back, imparting additional rotation to the cable quadrant. A mechanical lock prevents use of the thrust reverse lever when the power control is not in idle.

The input shafts at the engine fuel controller are concentric, the fuel shutoff shaft being the inner of the two. Arc of travel of the pilot's forward thrust lever causes slightly more rotation of the engine power shaft than does the thrust reverse lever.



SKETCH SHOWING POSITIONS OF ENGINE CONTROLS



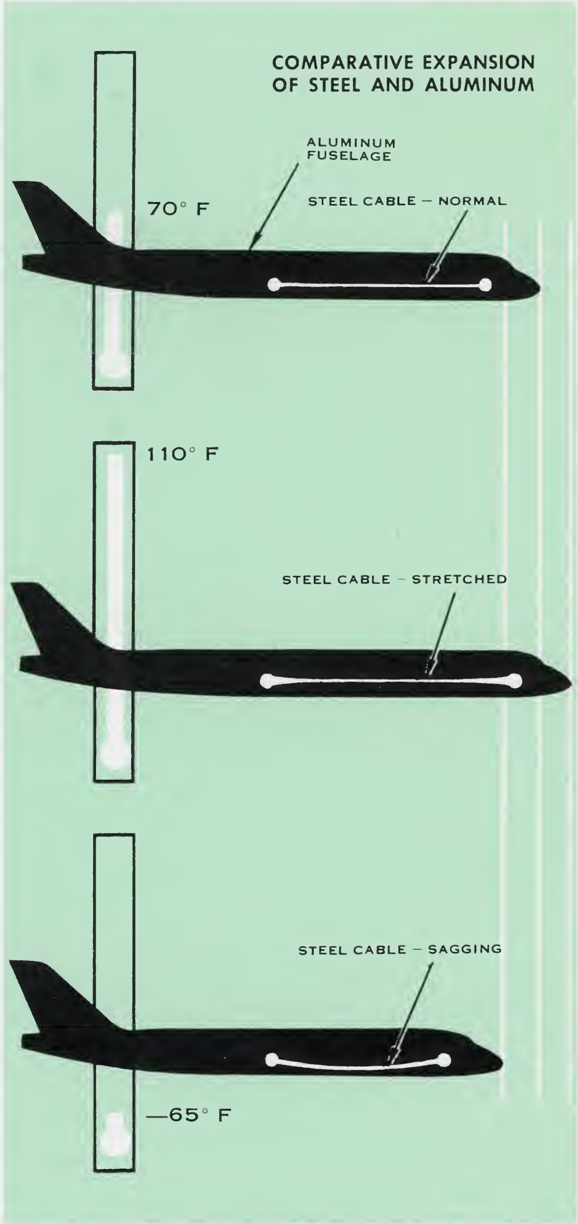
SCHEMATIC OF ENGINE CONTROL SYSTEM

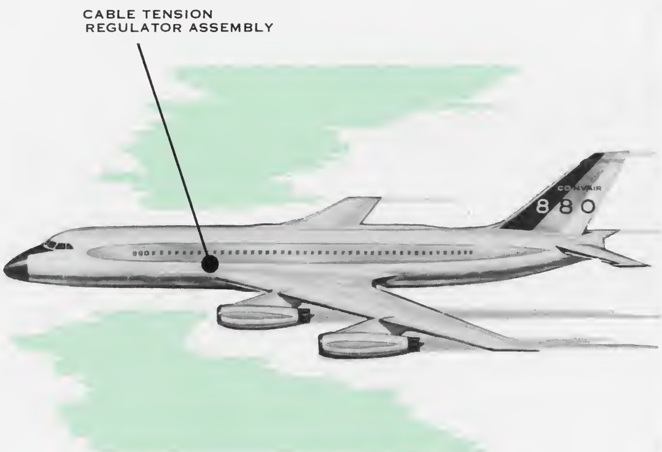
CONVAIR 880M/990
Cable Tension Regulator

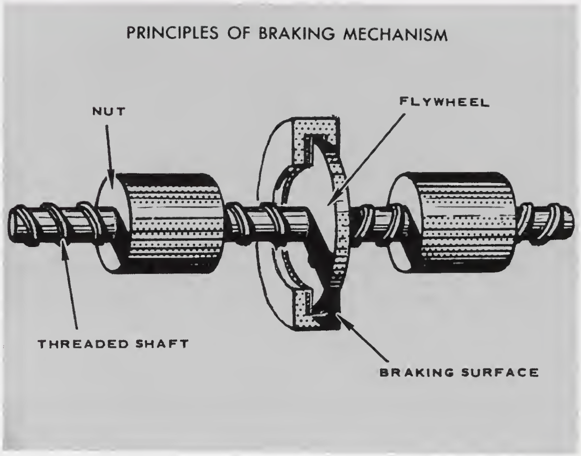
In these days of high-altitude long-range flights, aircraft are being subjected to many conditions not normally experienced by their lower-flying, shorter-ranged counterparts. One of these jet-age conditions is the rapid and extreme temperature changes that take place on routine flights. Taking off under normal weather conditions, climbing to very cold altitudes in a matter of minutes, and later landing at perhaps a desert air terminal where the temperature is 110° F, causes quite a stir in the dissimilar metals incorporated in the design of a modern aircraft.

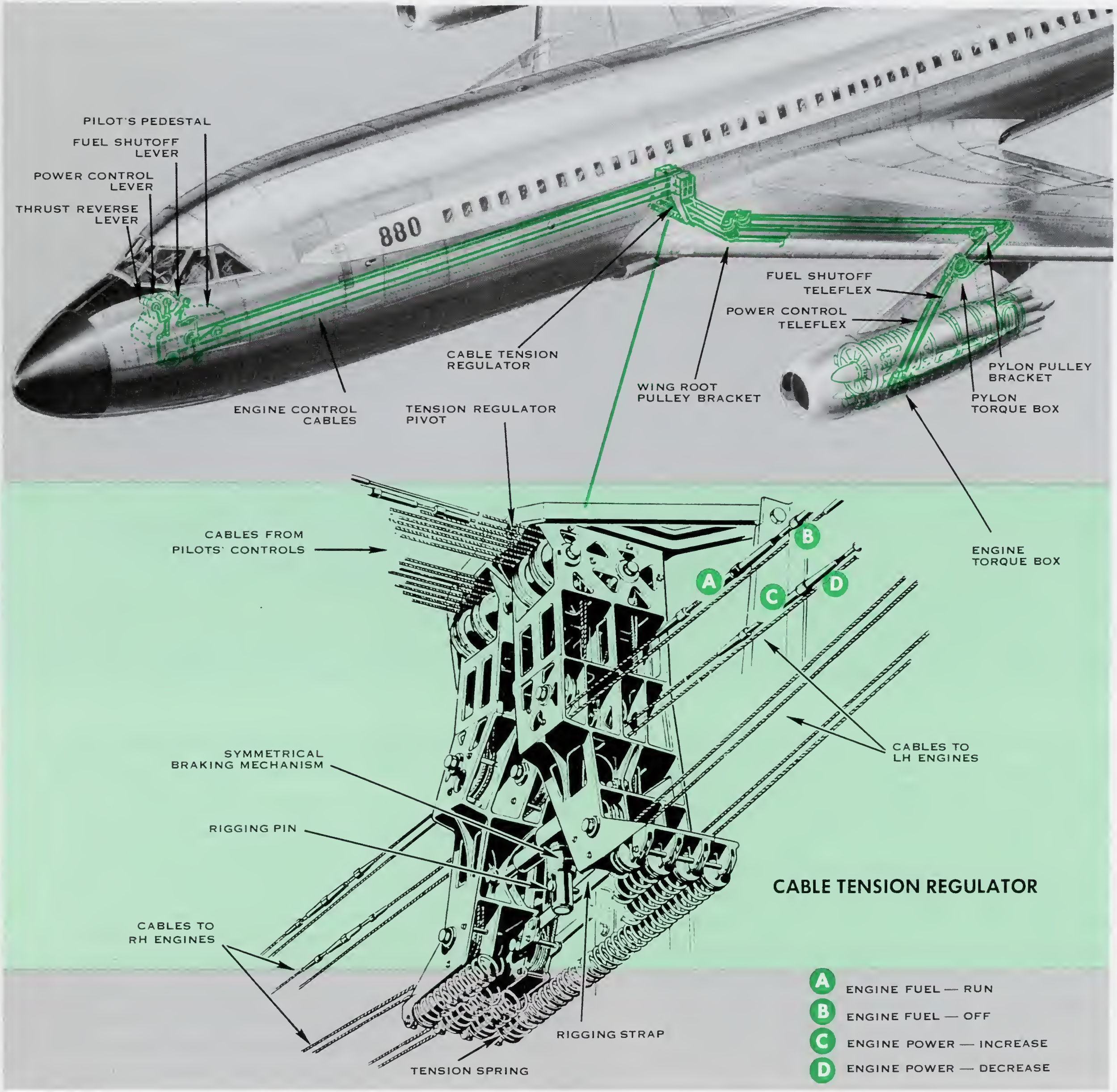
The difference in the coefficient of expansion between an aluminum airplane and its steel control cables would present a situation resulting in slack cables at cold temperatures and very taut cables at hot temperatures. As an example, at 160° F, an aircraft will expand .70 inch more than 100 feet of steel control cable, rigged for correct tension at 70° F. Uncorrected, this would put undue strain on the tightened system and, coupled with the added friction induced by pulleys and control mechanisms under strain, the controls would be difficult to operate. The opposite occurs when the temperature drops from 70° F to —65° F. The cable would then be slack because the airframe would be more than 1.00 inch shorter than the cable.

The engine fuel and power control cables, which extend through the unpressurized wing in proximity of hot compressor bleed air and de-icing ducts, pose problems associated with thermal variations and structural flexing. The solution to these problems took the form of a Convair-designed cable tension regulator that handles a total of 16 cables to all four engines. This compact single unit cable tension regulator is located at the center of the fuselage at the wing front spar. The engine fuel-power cable and pulley systems extend from associated quadrants below the cockpit floor at the pedestal, through the tension regulator, and out to the engine pylon torque boxes. From the









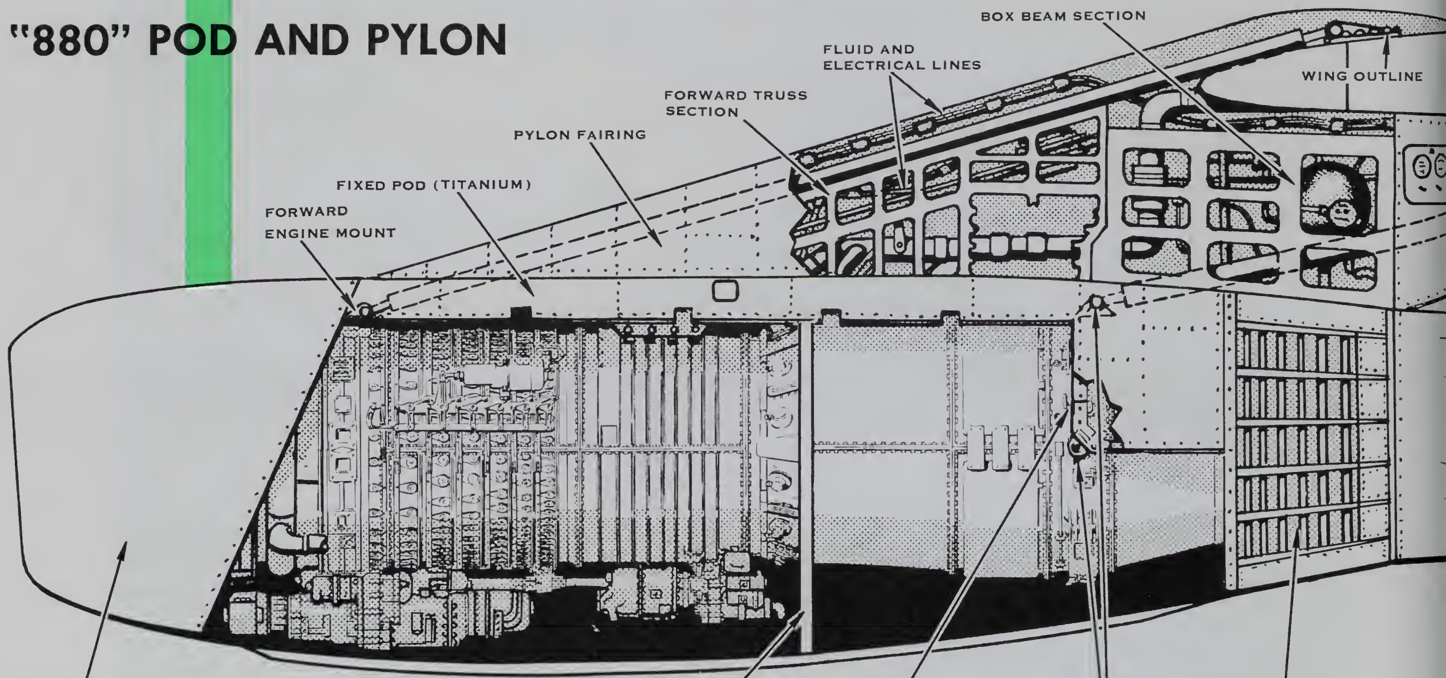
pylon torque boxes, the controls continue through teleflex cables to respective functions at each engine.

The heart of the 880/990 cable tension regulator is an ingenious mechanical device developed by the Pacific Scientific Company. Sometimes referred to as a braking mechanism, the unit consists of a shaft with opposing RH and LH high-lead threads and nuts on each end, with a captive flywheel in the center. The flywheel is between two braking surfaces and turns freely when centered. When an equal force is applied to both sides (as when the rig load changes), the nuts move, spinning the shaft and flywheel freely — as the thread pitches are added together. When the applied force is on one nut only (as when a control load is applied), the flywheel instantly comes in contact with a braking surface, freezing any motion of the nuts. Regulator springs maintain an equal load on both sides of the system until a control load is applied.

The primary function of the tension regulator allows the pulley brackets to pivot symmetrically opposite at the centerline of the airplane to compensate for the change in lengths of the engine control cables in the wings. Without the regulator, the temperature changes between airframe and cables would result in cable tension loads of approximately 15 and 180 pounds at the two temperature extremes.

The braking mechanism of the regulator also allows all cable tension loads to increase or decrease slowly in the event of different temperatures in the wings. This condition would result if two engines on one wing were being run up simultaneously, or one wing was in the shade and the other wing was in the sun.

"880" POD AND PYLON



The engine is suspended from the pylon at three points: aft, at mounts on each side of the turbine frame at the horizontal centerline and, forward, at the top of the compressor front frame.

The aft mounts are self-aligning spherical bushings into which slip 1¼-inch trunnion pins. The pins are clamped into a steel yoke, which in turn is bolted to the pylon structure. The yoke absorbs all of the engine's thrust. At the top of the turbine frame is a third mount to absorb side loads only. The trunnion pin in this bushing is a free pin and slides into a hole in the yoke.

The forward mount carries vertical loads only. The engine is suspended from a swinging link that allows the necessary engine thermal expansion. Side pads on the front frame contact matching pads on the pod doors to prevent differential side motion.

For ground handling there are two fittings at approximately the 5 and 7 o'clock positions on the turbine frame, and two side mount pads at the horizontal centerline on the compressor front frame.

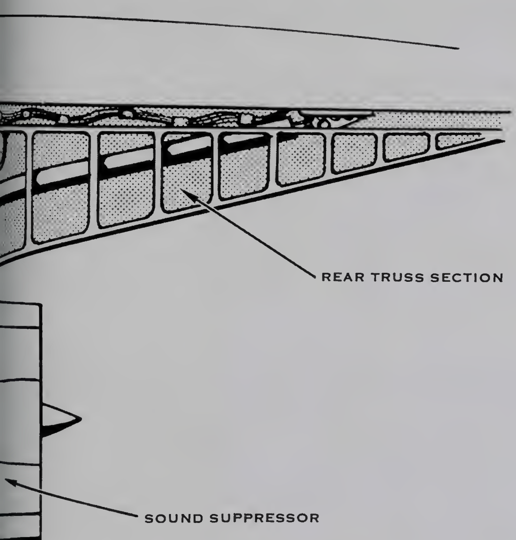
The pod consists of five major assemblies: the fixed pod (saddle), covering approximately the top third of the engine; two side panels (doors), hinged at the top and latched together along the bottom; the nose cowl; and the cowling that covers the reverse thrust unit. Side panels, nose cowl, and after cowling are interchangeable parts; the fixed pod and pylon assembly is removable, but not interchangeable since wing attachment differs for each of the four engines.

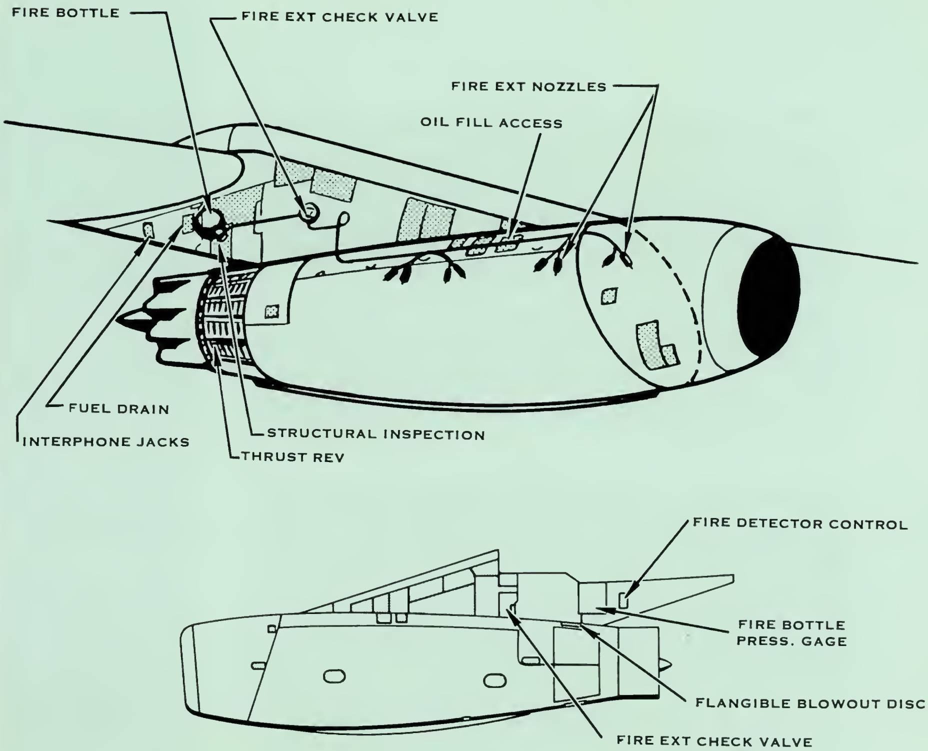
Most of the pod structural framing is fabricated from stainless steel. Skin on the side panels is aluminum alloy. Titanium is used for the air ducting, the firewalls, and in the thrust reverser and sound suppressor areas. All aluminum alloy that is not clad is coated with epoxy resin primer, resistant to solvent or corrosive action of any fluids likely to be used in the area.

The top panel of the fixed pod serves as a firewall to protect the pylon and wing from engine fire. Longerons of this panel are stainless steel, with titanium cross-frames and skin. Doors are provided in the cowling alongside the pylon for access to the upper pod area and, on the right-hand side, for access to the oil tank fill ports.

A stainless steel firewall at the aft flange of the compressor rear frame divides the pod, fore and aft, isolating the burner-turbine section from the compressor and accessory systems. Two fire doors, one forward and one aft, are provided in the left-hand hinged panel. The left-hand panel also has an access door for servicing the fuel collector tank, and the right-hand panel has a door for the ground start air connection. Cooling air for the combustion section is admitted through air scoops in the side panel and distributed by circumferential manifolds.

The side panels are locked together at the bottom with Hartwell latches. Props are mounted at each end of the panels to hold the panels open; when not





FIRE EXTINGUISHING SYSTEM AND ACCESS DOORS

in use, the props swivel up to clip to the side of the panel. If desired, the panels can be removed by pulling the hinge pins.

The nose cowl is attached to the forward flange of the fixed pod by three bolts. A stub duct between engine and cowl is attached to the engine by a V-band clamp. The stub duct is manifolded to admit ram air into the forward compartment for cooling.

Drain lines and holes, with a minimum diameter of ⅜ inch, provide drainage at various points during all normal ground and flight attitudes.

A fire warning loop is installed on the inner surface of each cowling side panel. To extinguish engine fires, a 6.5-pound bromotrifluoromethane bottle is carried in the pylon, with associated controls and plumbing into the pod. The plumbing on each wing is interconnected; the bottles in No. 1 and No. 2 pylons, for example, can both be used to put out a fire in either No. 1 or No. 2 engine.

The pylon is divided into three sections, a forward truss, a box beam section attached to the front main spar of the wing, and a rear truss that attaches to the center spar (inboard engines) or rear spar (outboard engines). The box beam is the main load-bearing structure; the aft engine mount yoke attaches to it, so that it supports the major part of the engine weight and transmits all the thrust. The box beam itself consists of two shaped castings of 2014 aluminum alloy.

All electrical and fluid lines come up through the forward truss — the electrical harnesses from the right-hand side of the engine, and the fuel and hydraulic lines from the left-hand side. The fluid lines run aft through the box beam, with the electrical lines routed above them. Both are separated by a partition. The bleed air lines come up through the box beam section. Since this area of the box beam is open through the firewall into the engine compartment, titanium is used in the framing, and an extra horizontal titanium firewall separates this area from that housing the fluid and electrical lines. Ventilation is supplied to the fluid line area.

There are eight access doors on the left-hand side of the pylon and four on the right, giving complete access to lines and control linkages in the pylon.

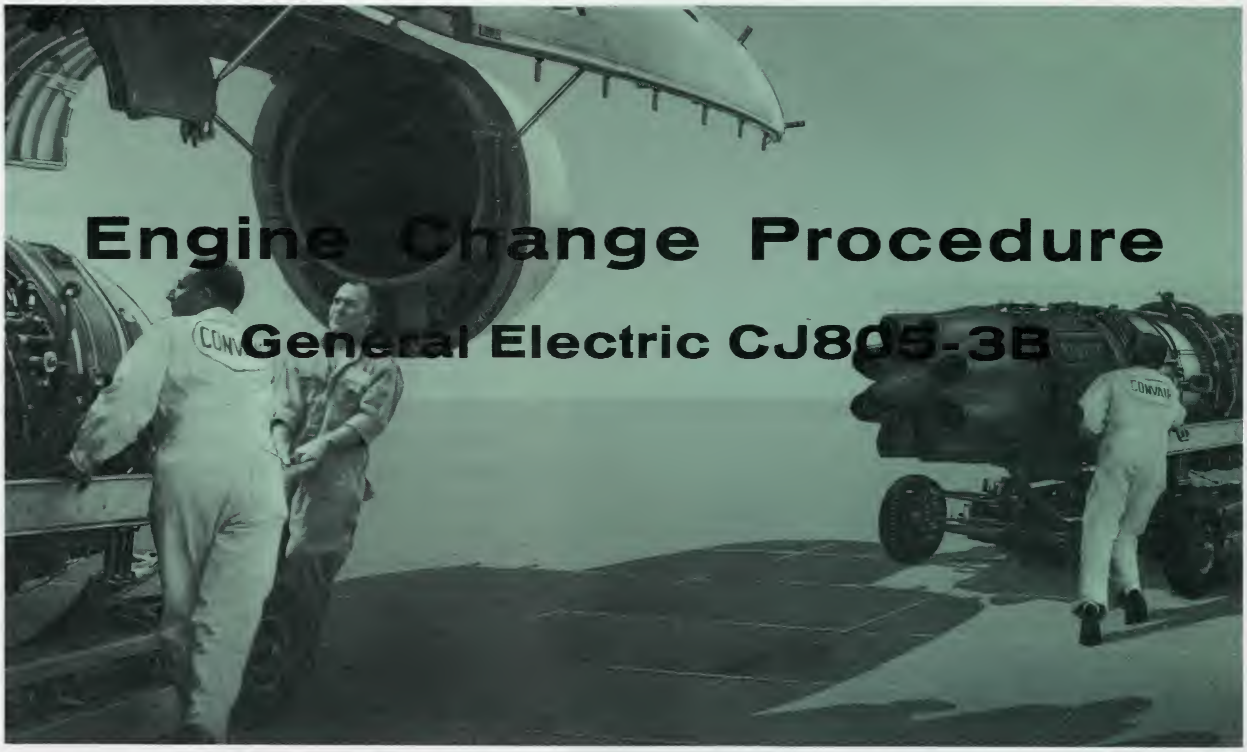
"990" POD AND PYLON

(See also pages 102 and 103)

The CJ805-23 main engine mount is located forward of the vertical firewall on the compressor rear frame, and just forward of the engine bleed air ports and fuel nozzles. A top centerline spherical bushing mates with a vertical pin that is part of the pod and pylon structure to take thrust and side loads. Vertical load is taken by two attachments at approximately the upper 45° positions on each side, mated with tangential links attached to the pylon structure.

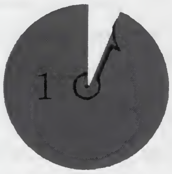
Engine Change Procedure

General Electric CJ805-3B



. . . A photographic analysis shows how engineering design saves "down time" on CJ805-3 engines . . .

The process of removing an "880" engine breaks down into the following three stages.



Access — opening pod doors and removing rear pod lower section.

Disconnects — disengaging fluid, air, electrical, and engine control lines.

Removal — attaching support fittings, positioning engine stand, uncoupling the engine mounts and lowering the engine.

The photographs that follow show this procedure, item by item. The process is actually faster than this summary might indicate at a glance. Design objective for the installation was removal and replacement of an engine in 30 minutes. A Convair five-man crew proved by demonstration that this objective could be achieved.

Most of the line couplings are quick disconnects, and most are concentrated in a pair of panels, one on each side. Aft engine mounts require removing two nuts each; the forward mount is attached by one bolt. Reinstallation time, it has been found by experience, is very little more and often less than removal time.

Installing a completely built-up engine is essentially the process pictured in reverse. No rerigging of engine controls is normally required; connections must be leak-checked, however, and the engine must be "trimmed out" before flight with the aid of a precision calibration unit. The Convair 880 and General Electric CJ805-3 maintenance manuals have detailed instructions on removal, installation, control rigging, and trimming.

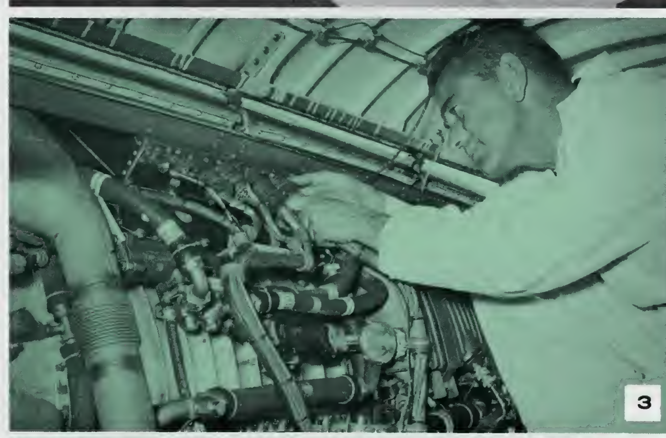
Access

To open pod doors, Hartwell latches are released, doors swung up, and support bars swung down and secured with ball-lock pins.

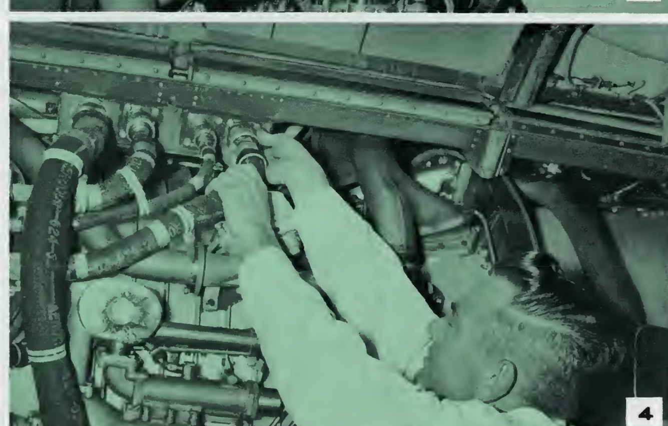
Aft lower pod section, under thrust reverser, is attached by four bolts, two on each side.

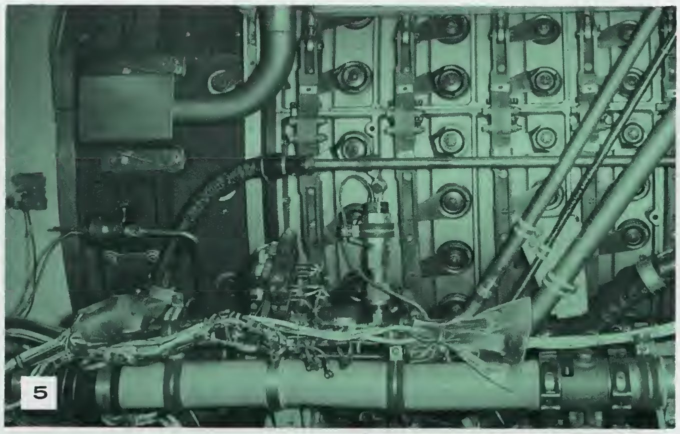
Disconnects

Six electric harnesses, pressure ratio static line, and one drain fitting are disconnected at a single panel on the right-hand side.

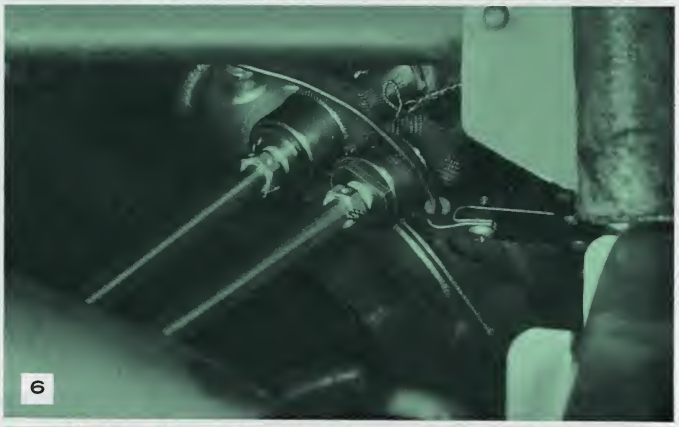


One fuel line, three hydraulic lines, and a drain are disconnected at the left-hand panel.



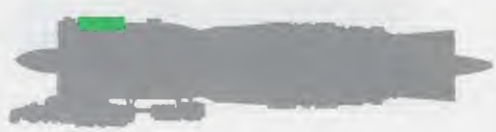


Inlet duct sensor harness to nose cowl is shown, already disconnected, at lower left-hand side. Bumper brackets, above, on forward compressor frame are removed for attaching engine stand ground support fittings.



Detail shows the two engine fuel control Teleflex disconnects; main bleed air line disconnect can be seen behind the teleflexes.

Starter bleed air line is disconnected. A similar Marman clamp joint (see Photo No. 6) disconnects engine from bleed air system.

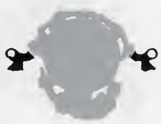


Closeup shows forward engine mount "dogbone" bracket, support link, and bond braid.

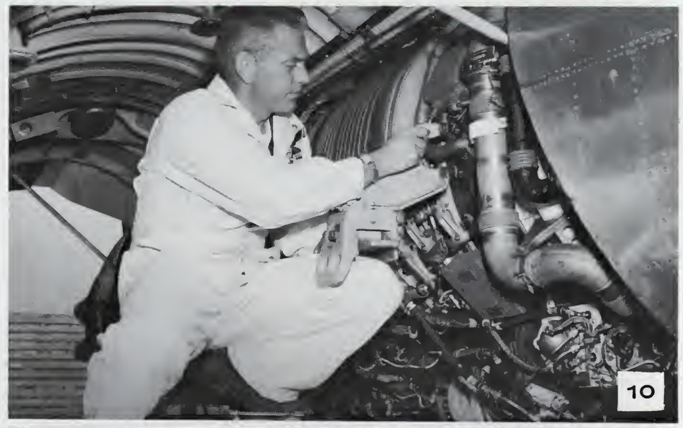
Closeup is of right-hand aft engine mount; left-hand is similar. The mounts are not disconnected until the engine stand is in place.

9

Removal



Ground support stand fittings are bolted to side mount pads on the compressor front frame, left and right, in place of the bumper brackets.



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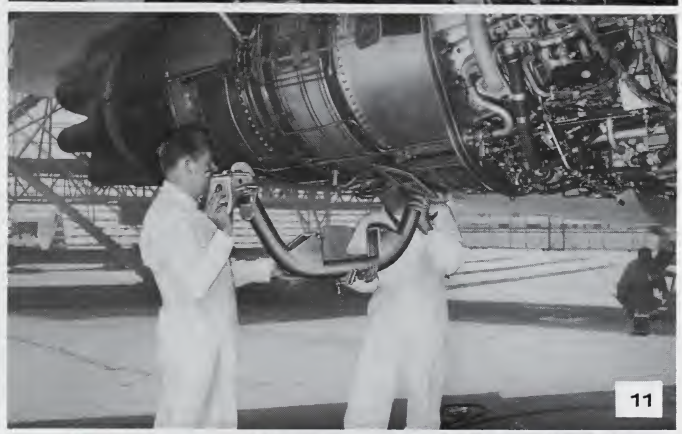
Aft ground support stand member attaches to bosses on lower segments of turbine frame.



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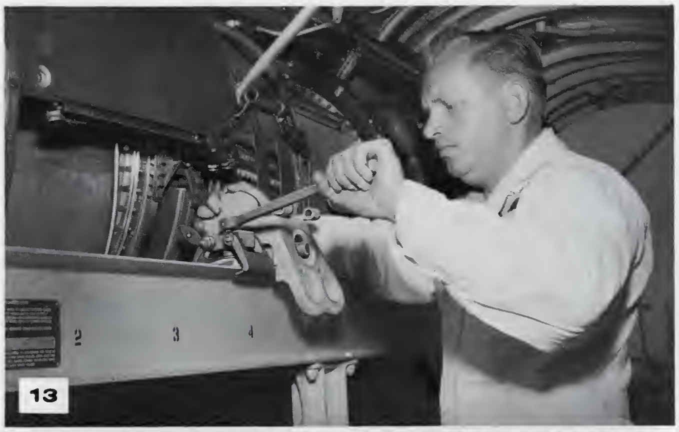
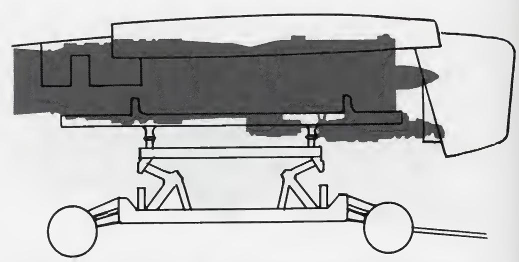
Stand is positioned carefully and raised until it just supports the weight of the engine. This is Air Logistics Corp. stand, with Convair-made fittings for the Convair "880" engine.

12



Support fittings are locked on stand rails.

Aft engine mount nuts are removed and lower half of clamp swung back to free trunnion. At forward mount, trunnion bolt is removed, to free the link from the "dogbone" bracket.



Engine is lowered, freeing side-thrust pin at 12-o'clock position on aft yoke; stand is backed until inlet nose cone fairing clears stub duct. Engine is then free of the pod.

Outboard engine can be wheeled away as shown; inboard engine must be backed far enough to clear nose cowl. Engine can be rolled or lifted to fixed stand for maintenance.

Thrust Reversers and Sound Suppressors

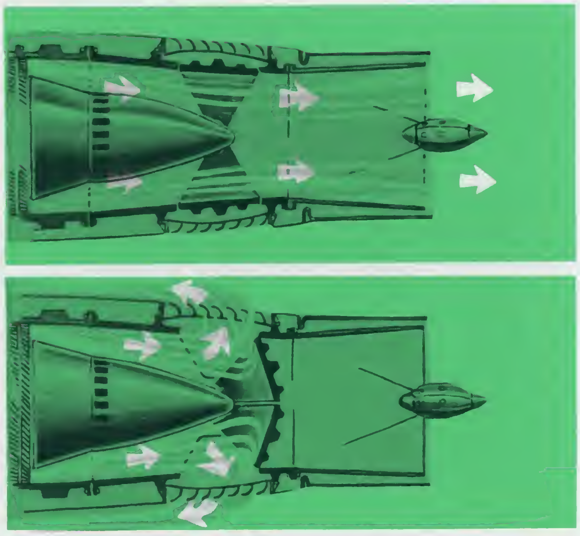
The General Electric Company, in close cooperation with Convair, developed an efficient thrust reverser and sound suppressor for installation on the CJ805-3 engine. The development program was initiated in 1957 and, in less than two years, production models of the thrust reverser-sound suppressor unit were ready for installation on the first Convair 880 jet airliner.

Thrust reversers brake the aircraft and shorten the landing roll, just as reversible pitch propellers perform this function on piston-powered aircraft.

The thrust reverser, constructed of corrosion-resistant steel, is an internal clamshell-cascade type, bolted to the aft end of the engine tailpipe. It consists of the tailpipe, blocker doors and mechanical linkage which actuate blocker doors.

Exhaust gases from the engine are diverted by two blocker doors that extend into the gas stream. When closed, the doors completely block the flow of exhaust gases, directing them through the turning vanes on each side of the reverser. With the reverser doors in the stowed (forward thrust) position, the doors conform to the shape of the tailpipe, allowing unrestricted flow of the engine exhaust gases aft through the reverser tailpipe and sound suppressor.

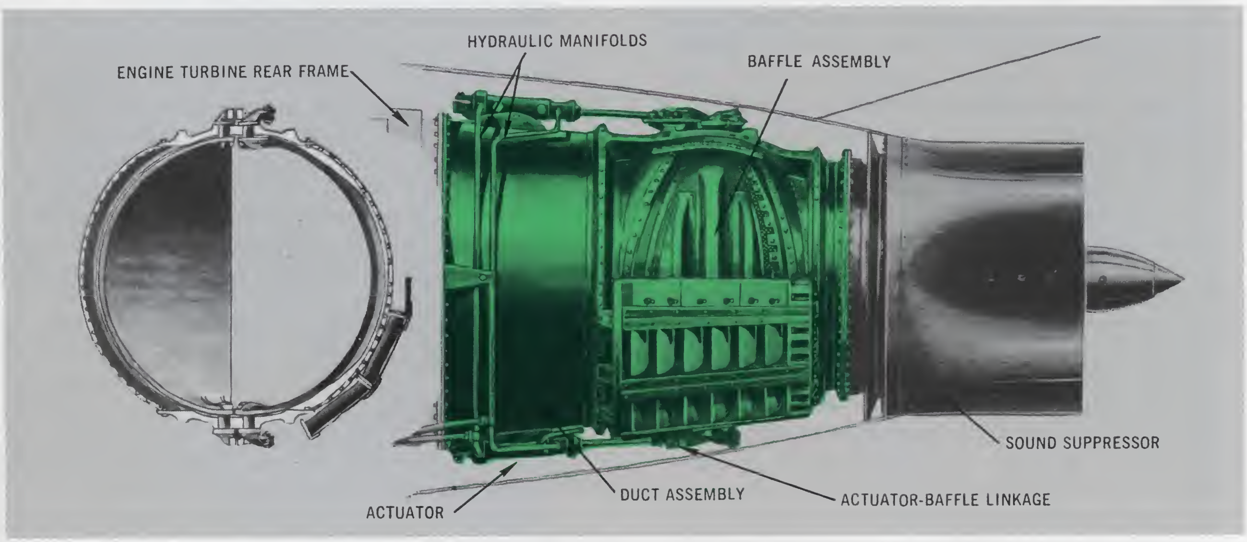
The fail-safe philosophy of the thrust reverser mechanism is that any single failure shall not prevent the thrust reverser from remaining in or near its last committed position. The doors are designed to have an overbalanced aerodynamic hinge moment to assure no inadvertent reversal in the event of a hydraulic and/or mechanical failure. A positive resultant hinge moment load is required to rotate the thrust reverse doors into the "In-Transit" range to reasonably assure no failures in transit.



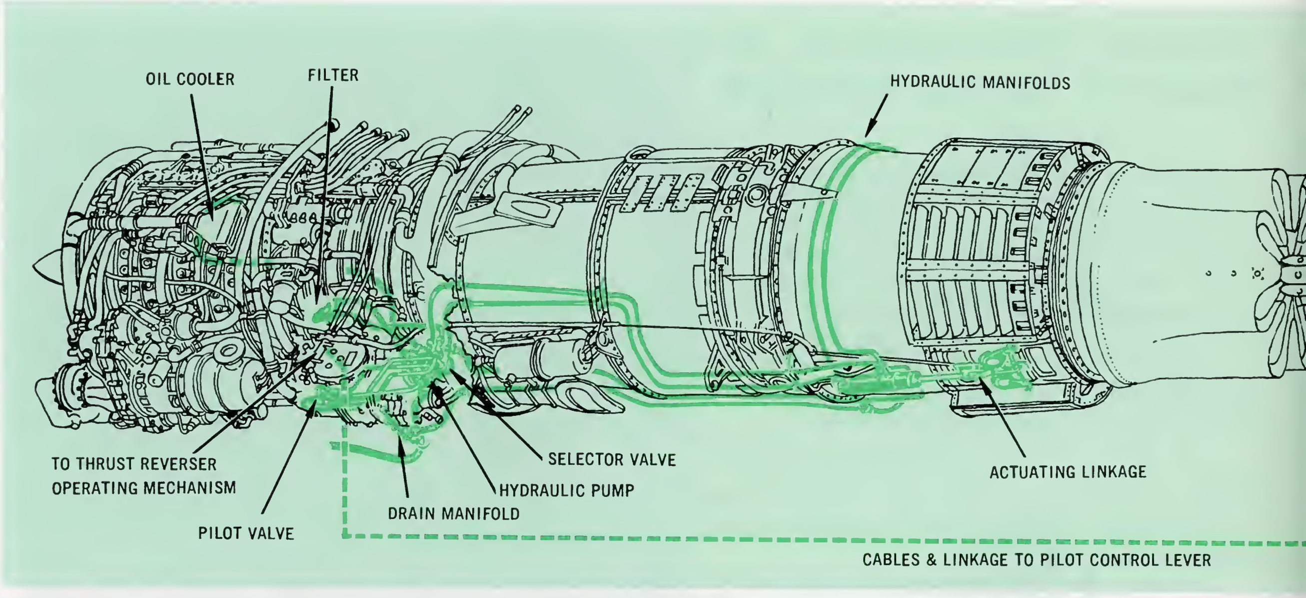
Top — Thrust reverser baffles in open position. Bottom — Baffles closed for thrust reverse action.

Components of the thrust reverser system include a hydraulic pump on the rear accessory gear box; a hydraulic oil filter located on the compressor rear case; a pilot valve on the engine fuel control (used to signal reverser position); a multi-purpose reverser control valve, mounted in tandem on the reverser pump; two hydraulic reverser actuators, mounted at top and bottom of the tailpipe; and the constant-speed-drive fuel/oil cooler. The thrust reverser system uses the same oil, related reservoir, and equipment that is utilized by the constant-speed-drive system.

In operation, the thrust reverser is actuated hydraulically to either the forward or reverse position by the thrust reverse lever. In the normal power operating range, the reverser doors are held in the stowed position by oil in the low-pressure hydraulic system, an



Thrust reverser with section showing open and closed positions of baffles.



Thrust reverser showing major component parts.

irreversible overcenter link, the door "stowed" seals, friction, and the aerodynamically overbalanced doors. In the reverse position, however, hydraulic pressure is reversed to extend the doors. The pilot valve, mechanically linked to the thrust reverse lever transmits a signal to the selector valve. Filtered, high-pressure oil, supplied by the engine-driven hydraulic reverser pump is then directed to the actuators, extending the doors.

A hydraulically-operated selector valve in the control applies oil pressure to the head or rod end of the actuators, as required, and allows oil in the exhaust end of the actuator to return to the oil reservoir. A pressure relief valve, mechanically synchronized to the actuators, bleeds off hydraulic oil to maintain a predetermined holding pressure when the end of the actuator travel is reached. Oil bled from the hydraulic pressure lines is returned to the inlet of the hydraulic pump, and return oil from the actuator is routed through the constant-speed-drive fuel/oil coolers to the oil reservoir (CSD compartment).

The thrust reverse levers are mounted on the forward part of each power control lever assembly and rotate up and aft to activate the thrust reverser. With the power control lever in the idle position, aft movement of the thrust reverse lever will cause an interlock to engage that restricts any movement of the power control lever while the thrust reverse lever is in an active segment of its operating arc. A thrust reverse idle detent, incorporated in the mechanism, gives the pilot four pounds detent feel at the idle thrust reverse position.

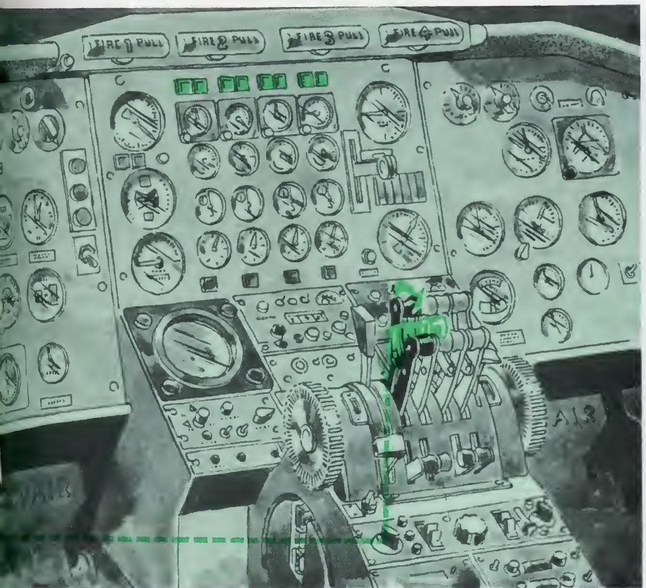
Thurst reverser position is indicated by colored lights in the pilots' compartment, and is achieved through microswitches. A mechanical thrust reverse interlock is operated from the reverser actuators; neither the thrust reverse lever nor the power lever can be operated beyond the idle power region until the reverser doors are in their proper position. Actuation of the thrust reverser levers illuminates blue IN-TRANSIT lights which go out when the reversers are in either the extreme open or closed position. When the thrust reversers reach their functioning position, amber REV-THRUST lights illuminate. When the reverser levers are returned to IDLE, the REV-THRUST lights go out and the IN-TRANSIT lights come on until the thrust reversers reach their stowed position, at which time the IN-TRANSIT lights go out. The thrust reverser position indicating system operates on power furnished by the 28-volt, d-c emergency bus.

The thrust reverser is designed to produce at least 5000 pounds reverse thrust at sea level static conditions, ICAO (International Civil Aviation Organization) standard atmosphere, with the engine at 100% (7460 rpm). Performance loss of the engine with the reverser in the forward thrust position does not exceed 1%.

Reverse thrust can be obtained at any forward ground speed below 200 knots and in cross winds up to 40 miles per hour. The reverser and actuation system are so well designed, the doors can be moved from the forward to the reverse thrust position in one second. The reverser can be used for periods up to 30 seconds during aircraft decelerations on the ground or during ground checkouts. At speeds below 40 knots IAS, the reversers are not used at maximum engine power because of possible re-ingestion of exhaust gases.

The sound suppressor on the Convair 880 mates to the aft flange of the thrust reverser and forms the exit portion of the exhaust section. The exit configuration of the sound suppressor resembles the petals of a daisy, clustered around a center spike. This configuration provides rapid mixing of the exhaust gases with the surrounding air, thus reducing the noise level.

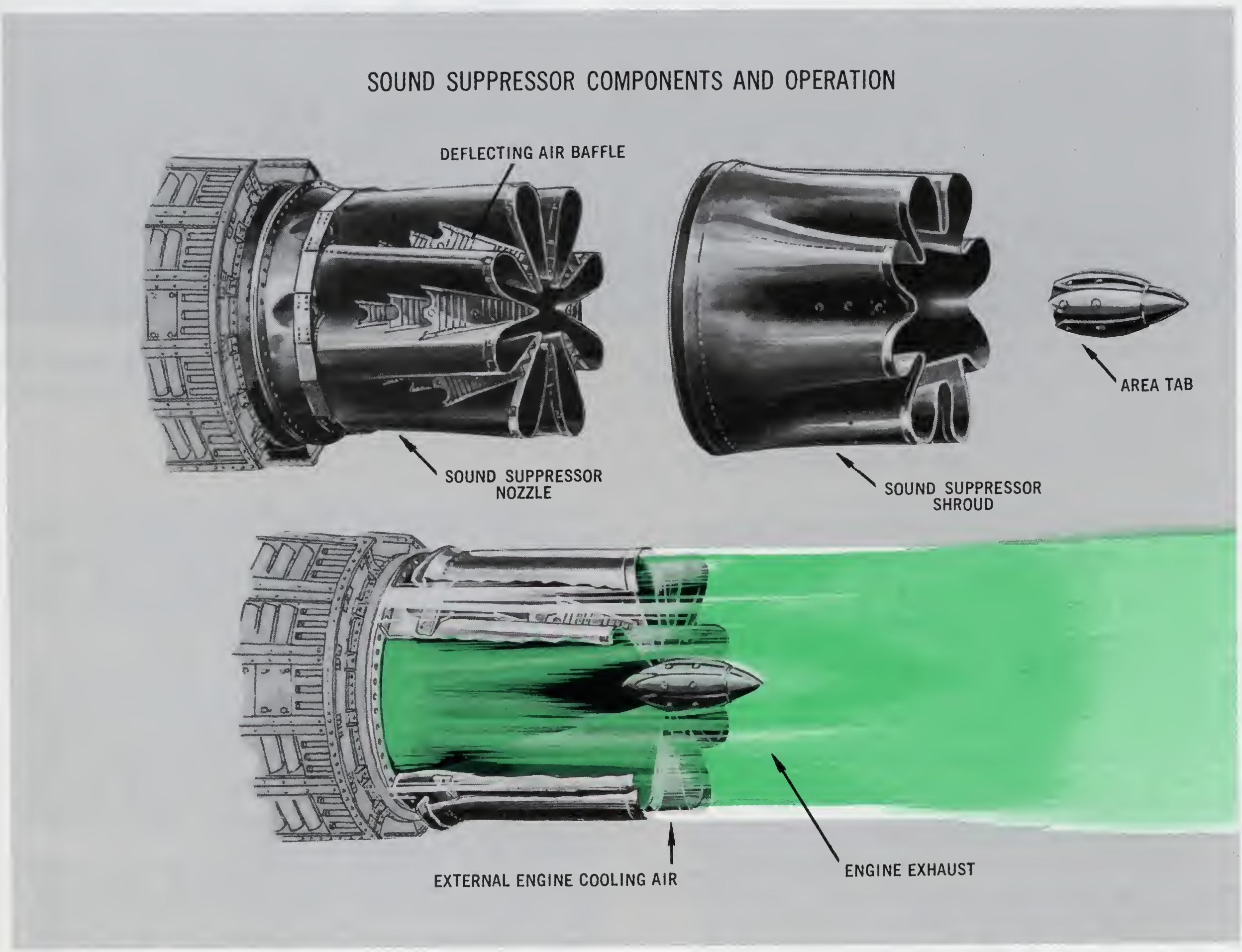
The development of the sound suppressor involved full scale testing of seven different types of configura-



Color shows lever in thrust reverse position. Black shows thrust reverser in OFF position.

tions. The current eight-lobed design was found to meet all of the Convair 880 requirements and was put into production. The design minimizes performance loss, is light in weight, and provides a structurally sound unit for long service life. The ejector fairing covering the exhaust nozzle further reduces aerodynamic drag.

The sound suppressor consists of an exhaust nozzle and a shroud, fabricated of welded stainless steel. The forward end of the shroud mates with the aft end of the airframe pod, and the flange at the forward end of the exhaust nozzle is bolted to the aft flange on the thrust reverser. The shroud follows the contour of the engine pod and serves as the external surface of the ejector nozzle. This type of nozzle requires a source of secondary air. At all conditions, the aft pod cooling air is routed between the shroud and the exhaust nozzle, thus increasing the mass flow of the exhaust gas stream. When operating at other than cruise conditions, air is supplied to the ejector from the four forward flush scoops by virtue of the ram pressure in flight and by ejector pumping action on the ground. The engine thrust losses with this ejector type of sound suppressor do not exceed 1.5 percent of the engine guaranteed gross thrust.



Convair 990 Engine and Pods

The General Electric CJ805-23 aft fan turbojet engine, which will be used to power the Convair 990, is almost identical to the CJ805-3B engine, which powers the Convair 880M, except for the addition of the aft fan.

Mated to the rear of the basic CJ805-3 engine, this unit is a free wheeling, single-stage fan that functions in a manner similar to that of a propeller, driven by engine turbine exhaust gases.

The operation of a fan, or bypass, type engine is the same as that of a conventional turbojet engine with utilization of additional inlet airflow ducted around the engine. The fan assembly, driven by engine turbine exhaust gases at its root, compresses the bypassed air with its outer blades, and discharges it with the exhaust. This action increases mass airflow which results in a large increase in overall engine thrust. The aft fan turns approximately 5760 rpm — 75 percent of engine rpm.

At sea level takeoff power setting, this engine provides 43 percent thrust increase with no increase in fuel flow over that of the -3 engine, a 20 to 40 percent improvement in climb thrust, and a 4 percent improvement in cruise thrust. In addition, a natural reduction in engine noise level is achieved, eliminating the need for engine exhaust sound suppression devices. Since the CJ805-23 aft fan engine discharges a larger mass of airflow at a lower jet velocity, there is less violent mixing of the exhaust and the surrounding air — the cause of most of the engine exhaust noise.

The aft fan design offers the least amount of compromise of the basic gas generator performance. The easy starting characteristics of the CJ805-3 engine are retained in the aft fan CJ805-23, and the acceleration characteristics of the aft fan engine — from idle to maximum speed in approximately 6 seconds — are almost the same as those of the straight turbojet engine.

In integrating the bypass ducts, the pod configuration of an aft fan engine can take several shapes, three of which are the single (combined engine-fan) inlet, the cheek-type inlet, and the annular (aft) inlet. Convair chose the single inlet design which produces the least drag of the three configurations. A forward concentric inlet is not only superior aerodynamically, but also is less apt to ingest foreign matter into the engine from the runways.

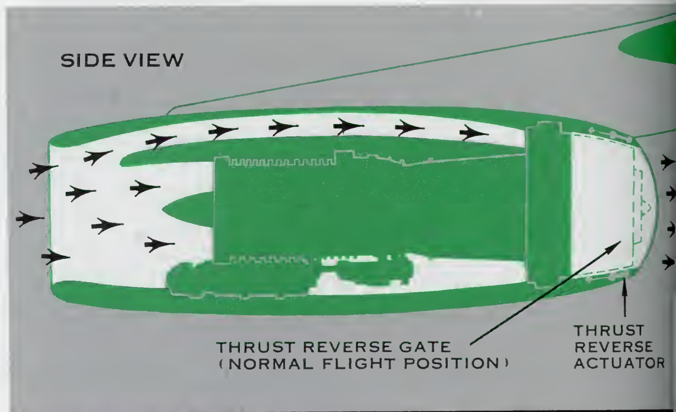


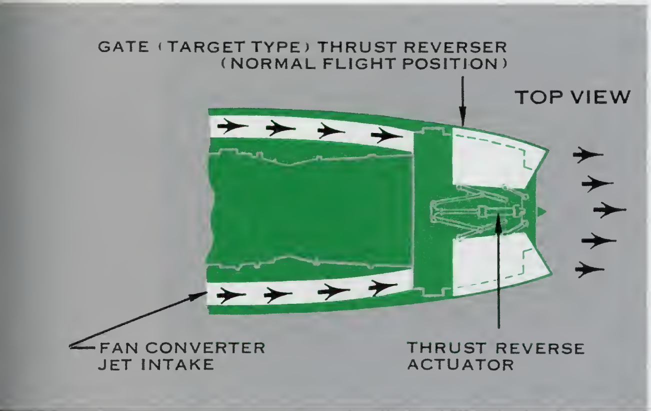
Photo shows comparable sizes of airflow duct and engine duct. Combined inlet configuration reduces drag.

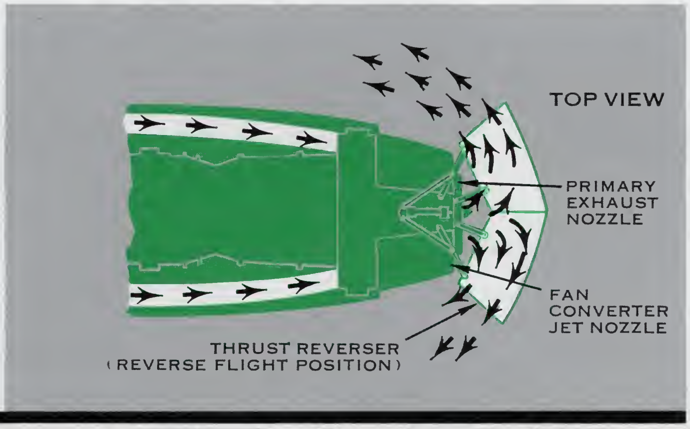
The pod, which contains the engine and the airflow ducts, is supported by a pylon which extends forward and downward from the lower surface of the wing. The inboard and outboard pylons are located at B.L. 266 and B.L. 495.5 on each wing.

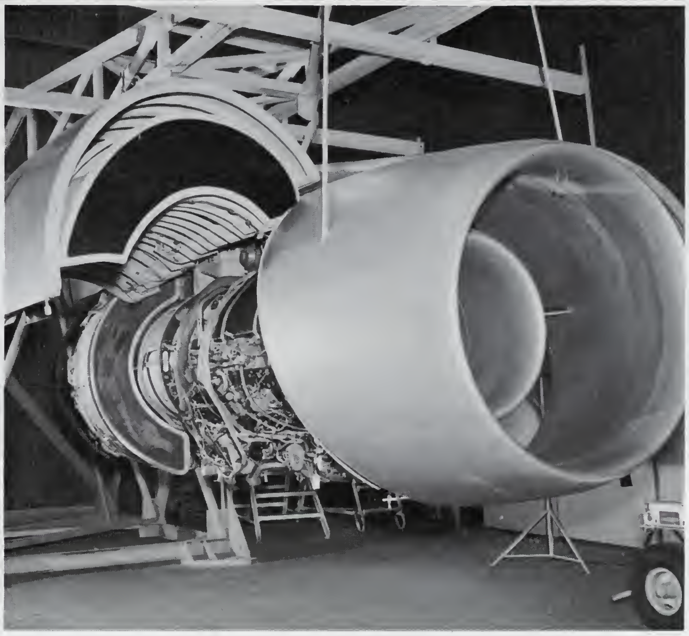
Each pod and its contents form an independent unit — a complete power source. The engine and its assemblies are interchangeable in any of the four positions.

The "990" pod, constructed of aluminum, steel, and titanium, is made up of six main sections: the nose cowl, the upper fixed pod structure, the two door panels, and two hinged fan ducts.

The inner and outer skins of the nose cone section are made of aluminum with formed aluminum frames. The leading edge of the nose cowl is dynamically etched to form lands that provide a space between the inner and outer skins for engine bleed air anti-icing.







"990" engine pod mock-up shows hinged door in open position. Door can be opened while engine is running.

Fan ducts in the "990" engine pod are hinged on each side and can be opened for easy access to the engine.

The pod doors combine aluminum and steel formers, and are skinned for the most part with aluminum. Titanium is used for firewalls and in areas of proximity to hot engine components. The hinged fan ducts have aluminum frames and skin.

The fan ducts and the doors of the engine pod are hinged separately on each side of the upper pod structure. Separating the doors from the ducts permits the doors to be opened independently for adjustment and maintenance of the lower accessories, while the engine is running. Duct screens are not required with the ducts in place.

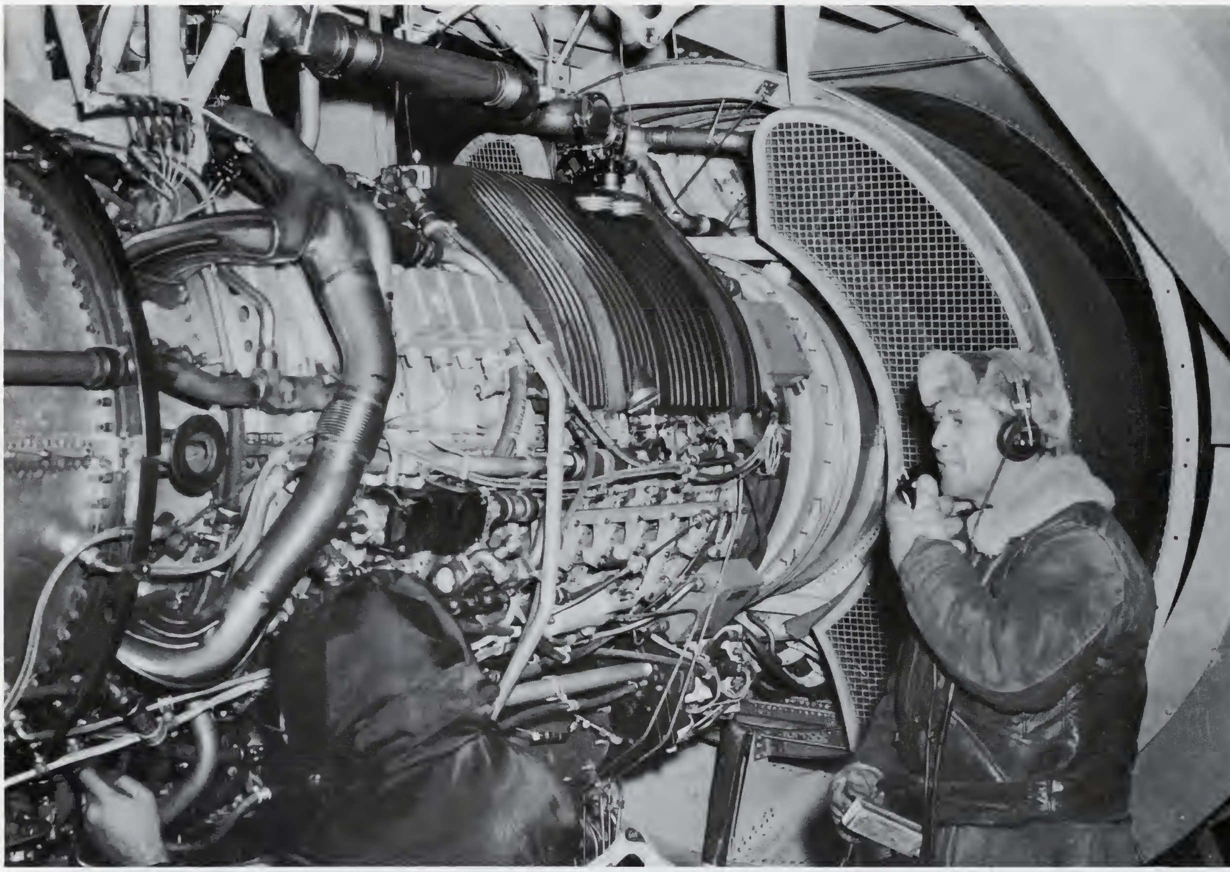
The thrust reversers for the "990" are designed specifically for the CJ805-23 engine by General Electric, and are an integral part of the power plant. They are of the simple, fast-acting, target (clam shell) type, and provide approximately 37 percent reverse thrust with a minimum of re-ingestion.

A pair of blocker doors (clam shells) rotate and move aft to the closed position so as to divert the exhaust gases forward. When stowed, the blocker doors fit around the concentric exhaust outlet to form the aft end of the pod.

The thrust reverser system is actuated by links and lever arms, powered by two hydraulic actuators, and is operated with the same controls and in the same manner as that on the Convair 880. The thrust reverser actuators are accessible for service and can be removed with the engine installed.

The reverser is designed to extend in two seconds and to retract within six seconds. It is intended to be operated on the ground only at airplane speeds of 60 to 200 knots.

Provisions are made for ease of ground servicing, routine maintenance of engine and accessories, replacement of parts, and complete engine changes.



Convair's 990 GE CJ805-23 engine in special test rig undergoes anti-icing tests in Minnesota winter.

Pod Inlet Anti-Icing

Convair 990

Basic design and principal elements of the "990" pod anti-ice system were proved out in the "880" test program when a built-up pod and engine were taken to Mt Washington for test runs. Mt Washington, while maintaining without much argument its claim to the "world's worst weather," has certain disadvantages for a test project; the weather is so extraordinarily bad that personnel and equipment may be isolated for days at a time.

When it came time to put the "990" installation through equivalent tests, it was decided to conduct them at Hopkins, Minnesota, near Minneapolis, where Research, Inc., has test facilities available. Minnesota usually has no trouble supplying below-freezing temperatures during the winter, and, if anything breaks down, parts can be obtained and repairs made without major delays.

The test rig was fabricated at the Convair plant in San Diego, California. It consisted of an intake duct with a bellmouth, a frame and housing for the engine, and an ejector duct nearly 30 feet long. Function of the ejector duct was to furnish airflow over the outside of the pod and to increase intake velocities, simulating flight conditions as closely as possible.

The negative pressure caused more air to flow through the bellmouth, which resulted in increased velocities. At idle speed (60% rpm) the velocity in the bellmouth was equivalent to an airspeed of 85 knots; at climb setting (97% rpm), velocity and pressure were equivalent to approximately 300 knots at 5000 to 6000 feet pressure altitude.

It took approximately six weeks to put the test equipment together, ship it to Minnesota on flatcars, and set it up with the proper instrumentation. The equipment included vibration pickups, temperature recorders, complete engine and anti-ice control panels, and a large manometer board with multiple mercury columns for indicating pressures at numerous pickup points.

Once in readiness, the tests were run rapidly whenever the weather wasn't too uncooperatively mild. To supply icing, test engineers created a lattice of water pipes, placed in front of the bellmouth. Special nozzles mixed compressed air and water and sprayed it into the airstream, at whatever rate was desired. Water droplet sizes of 10 to 25 microns were obtained. Rate of flow varied from half a gallon to five and six gallons per minute.

Many runs were made at "ideal" icing temperatures, from 15° to 25°F, and at temperatures down to almost zero. It was established that the inlet surfaces would be kept evaporative-dry at all climb, cruise, and hold engine control settings, under maximum continuous icing conditions. With engine at idle, the surfaces would still be running wet.

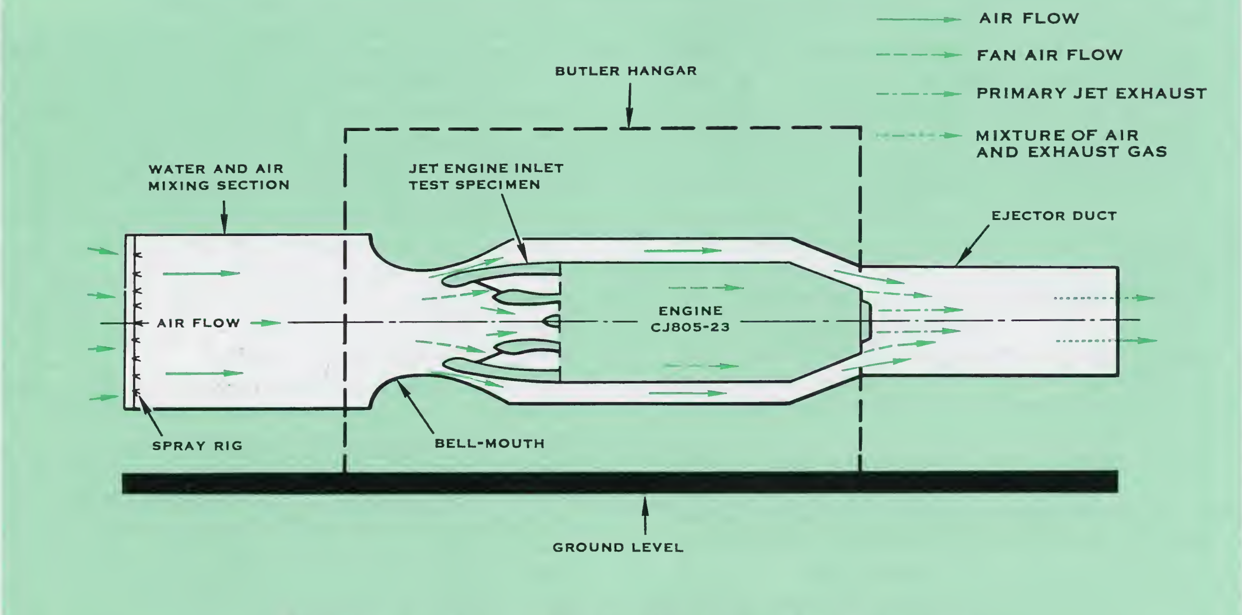
Because of the short time involved for descent through an icing cloud, runback and refreeze did not pose a serious problem. There was no overheat of the surfaces at any setting.

The only changes recommended were a few minor corrections in bleed air flow volume and bracketry. Convair continued the test runs for some days after the FAA representatives left. By the time the exhaustive program ended, the tests had proved the original design predictions to be accurate, and the system able to handle icing conditions equal to the maximum possible in flight.

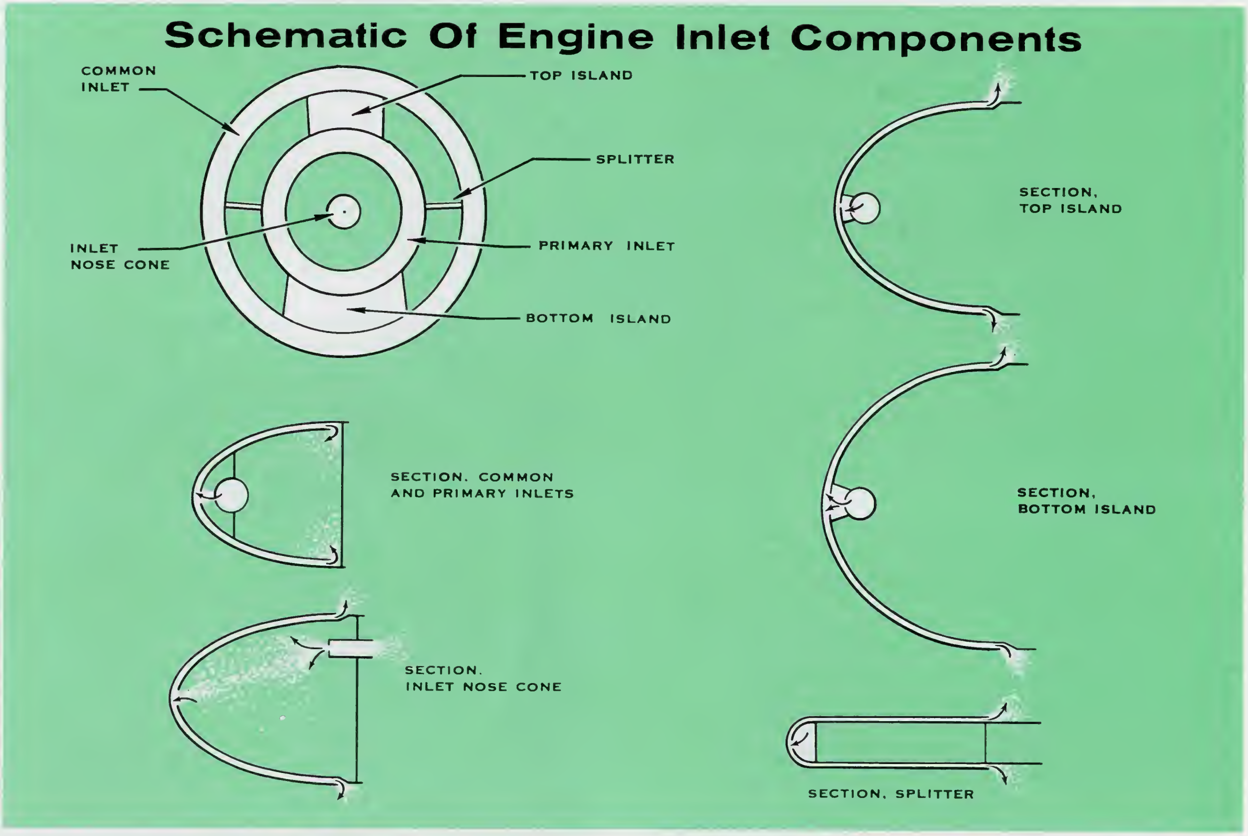
In icing conditions, ice can build up rapidly on engine nose cowls and compressor inlet components. All versions of the General Electric CJ805 engines that power Convair 880 and 990 aircraft use 17th stage compressor bleed air to heat the front frame struts, nose fairing, and inlet guide vanes.

Engine front frame and guide vane anti-ice systems are part of the engine assembly, developed by General Electric and tested by them in the subzero blizzards at the top of Mt Washington, N.H. No less important is an anti-icing system developed by Convair for the nose cowling forward of the compressor inlet. In the "880," there is only the leading edge of the pod and the hub fairing to be protected. In the "990" there are the forward outer ring, or common inlet; an inner compressor ring, or primary inlet; the hub fairing; the "islands" at the top and bottom between inner and outer rings; and the "splitters" that divide the large air ducts which lead back to the aft fan. All these must be protected against ice buildup, which could break loose and damage compressor or fan blades as well as interfere with the airflow.

Photo shows engine inlet parts requiring anti-icing. Ice detector probes are at top.



Schematic Of Icing Laboratory



Inlet Anti-Ice System

The pod common inlet and primary inlet leading edge assemblies each consist of .090 alclad with chemically-milled passages, .040 deep and 1-3/4 to 2-1/2 inches wide, separated by 7/16-inch lands; inner skins of .025 alclad, spotwelded to the lands of the outer skin; and a "piccolo" tube of .020 titanium, perforated along the forward side with 1/16-inch holes that direct bleed air flow at the leading edges.

The tubes are attached to the skin by angles that seal off the forward four inches of the leading edges into D-ducts. Hot air is directed at the foremost point of the leading edge, and flows back through the milled passages to heat approximately the forward six inches of the inlets. Aft of the passages, the air is discharged into the engine airstream through 3/16-inch holes, drilled through the skins. There are four groupings of discharge hole patterns in the inner cowl, six in the common inlet cowl.

Splitter leading edges have double .020 titanium skins with spacers in between. Both skins are continuous around the leading edge; the inner skin is drilled to allow passage of hot air to the inner surface of the outer skin. The interior of the leading edge is a D-duct, which is fed with bleed air from a tube teed into the anti-ice ducting. The hot air flows back between the skins and vents five inches aft of the leading edge.

In the islands, half-inch piccolo tubes run down the centerlines. Hot air flows back between inner and outer skins through transverse chemically-milled channels, discharging at the island aft edges.

Airflow to the components is metered by the small holes in the piccolo tubes; the pressure is regulated by an anti-ice control valve set at a 13 ± 2 psig downstream pressure. Piccolo tubes are of titanium; islands and cowl leading edges are of aluminum alloy. For the skin, a temperature of approximately 300°F should not be exceeded. During flight, the airflow around the heated components will keep the temperature within a safe margin, but for ground run-ups, where there is no forward motion, overheat must be guarded against. A temperature sensor in the outer ring will shut off the hot airflow to the inlet before a dangerous temperature is reached.

In both "880" and "990" aircraft, a double probe ice detector, in the common inlet, signals when ice is encountered. Each probe has small holes in the forward face; one is constantly heated by an electrical element. When ice forms on the unheated probe, ram air pressure differential between the two probes actuates an anti-ice switch. In the "880," the anti-ice switch automatically actuates the major anti-ice systems — engine and pod, windshield, wing, and empennage. In the "990" by customer request, the anti-ice systems are manually operated at the pilots' discretion. The probe switch illuminates an ice warning light on the pilot's overhead panel.

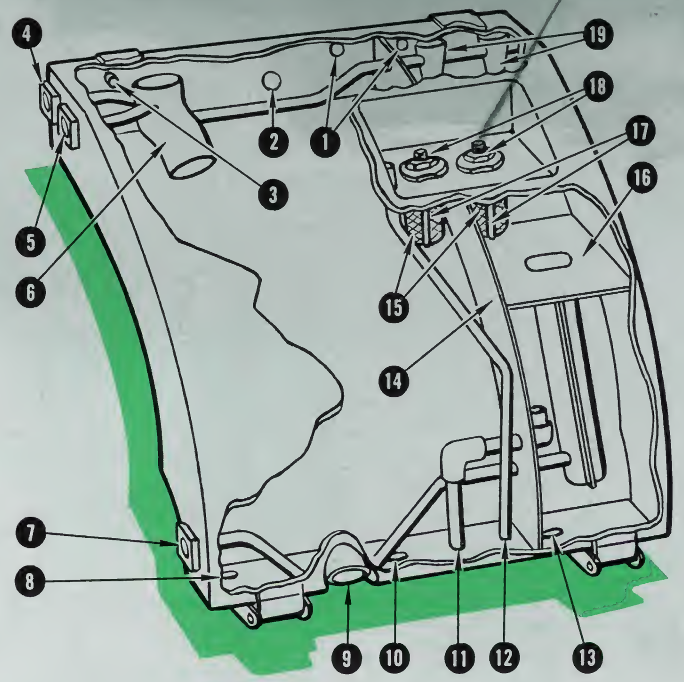
Convair 880
Engine Oil System

The oil system on the Convair 880 is a pressurized, recirculating system that has two important functions. Its first and primary function is to lubricate the bearings and gears on the engines; its secondary function is to cool them. An oil system reservoir, mounted on each engine, is separated into two compartments. (See cutaway diagram of oil tank.) One compartment supplies oil for the engine, the other compartment contains oil for the hydraulic section of the a-c generator constant speed drive and also for the engine thrust reverser system.

The two compartments of the oil reservoir are connected by an external pressure equalizing line ported to the expansion spaces provided in each compartment. The engine oil compartment holds 4.15 gallons of oil with an expansion space of 1.26 gallons. The CSD and thrust reverser compartment holds 1.72 gallons of oil, with an expansion space of 0.50 gallon. With the tank filled, the engine has a normal operating capability of 13.6 hours. At the end of that time the engine compartment should contain approximately 1.10 gallons and the CSD compartment 1.53 gallons. This reserve is sufficient to permit the engine to be inclined 30° up or down, or rolled into a 20° left or right bank without uncovering the oil outlets.

Hand-fill or gravity servicing ports for each compartment are located near the top of the tanks. A dipstick that forms an integral part of each gravity fill cap is provided, and the gravity fill ports are recessed into the tank so that the caps protrude only slightly. A de-aerator is incorporated in the scavenge return line of each compartment to separate the entrained air from the oil prior to the starting of oil recirculation.

The engine oil supply system is divided into three subsystems: supply oil, scavenge oil, and sump pres-



Engine Oil Tank Cutaway

1 PRESSURE EQUALIZER PORTS
2 VENT OUTLET
3 SUMP VENT INLET
4 CSD RETURN
5 ENGINE SCAVENGE RETURN
6 DE-AERATOR
7 THRUST REVERSER SUPPLY
8 ENGINE COMPARTMENT DRAIN
9 OIL LEVEL TRANSMITTER PORT
10 ENGINE SUPPLY
11 CSD SUPPLY
12 SCUPPER DRAIN
13 CSD COMPARTMENT DRAIN
14 COMPARTMENT DIVIDING BULKHEAD
15 FILTER SCREENS
16 CSD ANTI-G BAFFLES
17 DIPSTICKS
18 FILL PORTS
19 DE-AERATOR

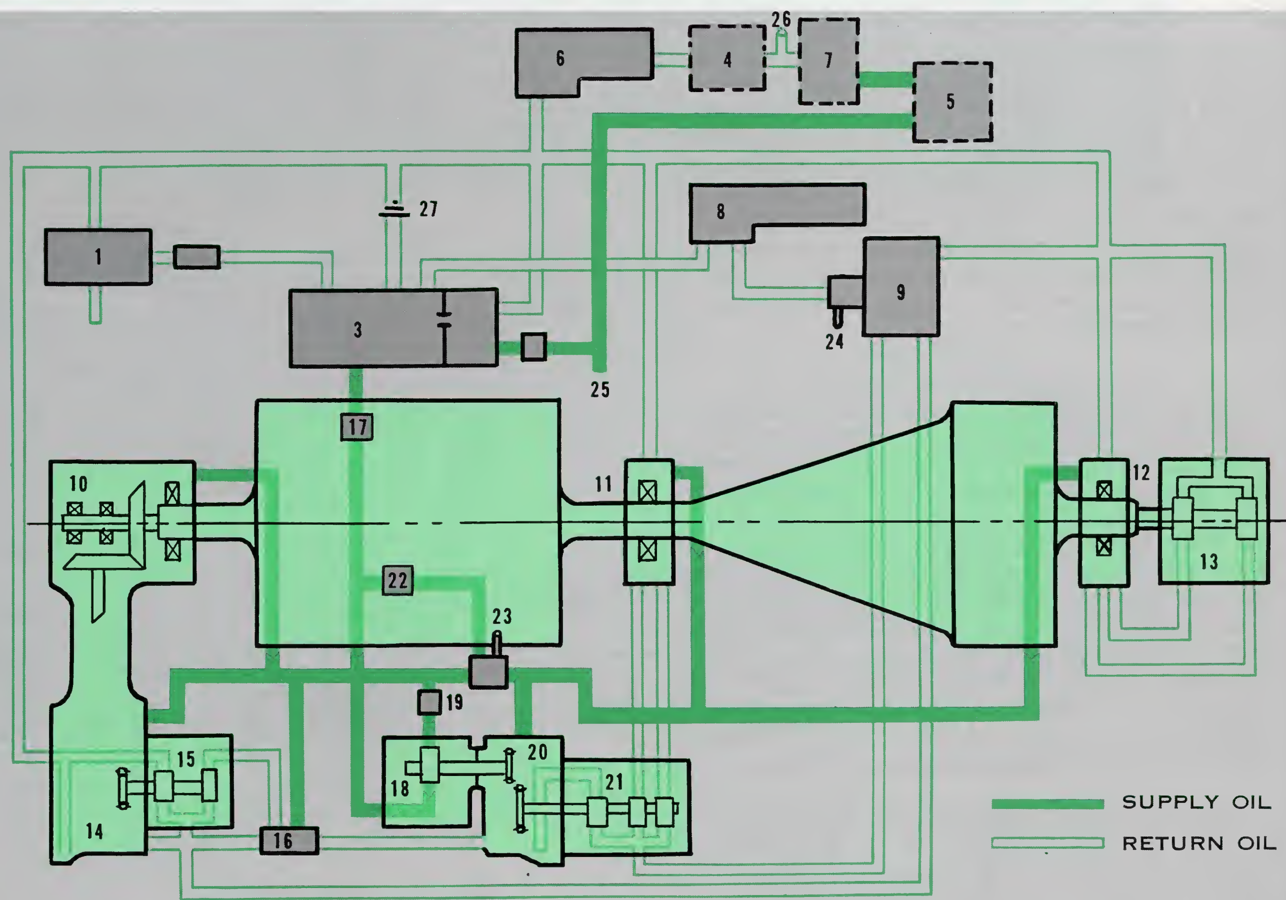
surizing. (See lubrication system schematic.) Leaving its reservoir, the supply oil flows to an engine-driven supply pump which increases the pressure from 20 psig to 65 psig (depending upon engine speed) and discharges the oil to the supply oil filter through an anti-leak check valve. Filtered oil is then directed to a T-fitting which divides the flow to supply the front gearbox and the No. 1 engine bearing, the transfer gearbox (front accessory case), and the horizontal drive shaft damper bearing.

Oil is routed to five oil jets in the front gearbox and No. 1 bearing area through the No. 5 compressor front frame strut. Seven oil jets distribute the oil in the transfer gearbox and one additional jet supplies oil to the horizontal shaft damper bearing. The T-fitting line also supplies oil to the rear gearbox where four jets distribute the oil. A line through the No. 5 strut of the compressor rear frame carries the oil to the No. 2 bearing area where four jets distribute the oil. Oil to lubricate the No. 3 bearing is routed through the No. 3 strut of the rear turbine frame where three jets distribute the oil over the No. 3 bearing.

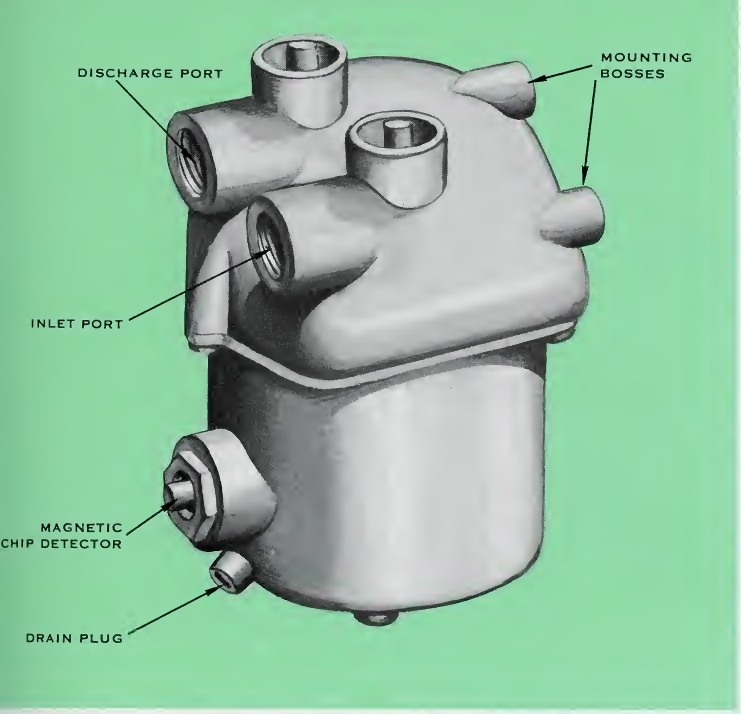
The oil supply pump is a single element pump with a rated flow of 9.5 gpm (60 psi) at 100% engine speed, based on a pump inlet pressure of 25 to 30 in. Hg (absolute) and an oil temperature of 300°F. After leaving the pump, oil enters a filter through a single inlet port, passes through the cartridge into the inner chamber and then flows out the discharge port. If the filter becomes clogged, oil is bypassed across the filter through a pressure relief valve to the discharge port. A differential pressure of 14 to 16 psi across the filter is required to unseat the relief valve. A port is provided to drain the filter prior to removal for cleaning or inspection.

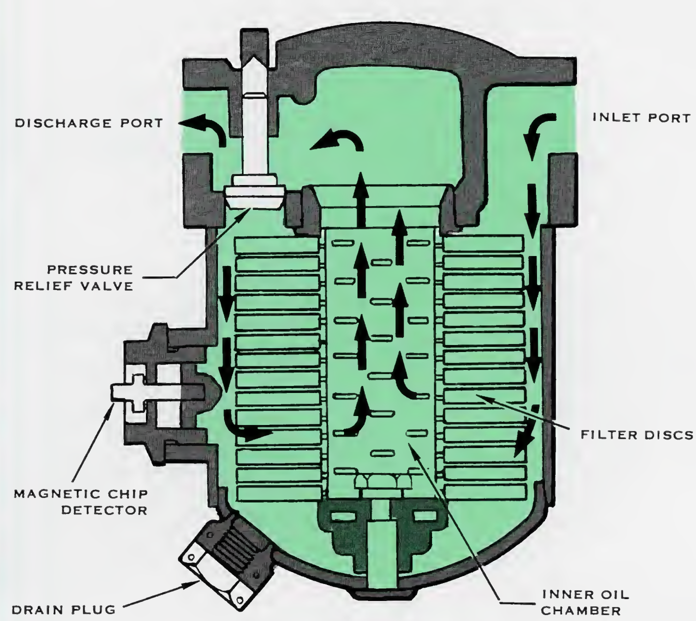
The body of the filter contains a magnetic chip detector adjacent to and above the drain plug. The filter element is comprised of a stack of "pancake"

Lubrication System Schematic



1 SUMP PRESSURIZING VALVE
2 TANK PRESSURIZING VALVE
3 OIL TANK
4 AIR-OIL COOLER
5 CSD OIL TEMPERATURE SENSOR
6 CSD FUEL-OIL COOLER
7 CONSTANT SPEED DRIVE
8 ENGINE FUEL-OIL COOLER
9 SCAVENGE OIL FILTER
10 VERTICAL DRIVE AND NO. 1 BEARING AREA
11 NO. 2 BEARING AND SUMP
12 NO. 3 BEARING AND SUMP
13 NO. 3 BEARING SCAVENGE PUMP
14 TRANSFER GEARBOX
15 TRANSFER GEARBOX SCAVENGE PUMP
16 DAMPER BEARING
17 SHUTOFF VALVE
18 SUPPLY PUMP
19 SUPPLY OIL FILTER
20 REAR GEARBOX
21 REAR GEARBOX SCAVENGE PUMP
22 PRESSURE RELIEF VALVE
23 OIL PRESSURE TAP
24 SCAVENGE OIL TEMPERATURE TAP
25 TO THRUST REVERSER SYSTEM
26 FROM THRUST REVERSER SYSTEM
27 SUMP PRESSURIZING CHECK VALVE





Oil Filter

Oil Filter Schematic

elements capable of filtering out particles exceeding 46 microns in size. With oil at 150°F and a flow of 15 gpm, the pressure drop across a clean filter is approximately 6 psi; estimated maximum pressure drop across a clogged filter is 23 psi. In addition to the magnetic chip detector, an electrical chip detection pickup is provided in the filter. By attaching a milliammeter to this pickup and completing the circuit, the quantity of ferrous deposits in the filter sump can be determined.

Oil in the bearing sumps, damper bearings, and accessory cases is scavenged, filtered, cooled, and returned to the engine section of the oil tank, by means of three scavenge pumps where it is de-aerated. Capacity of the scavenge subsystem is approximately two and one-half times the actual amount of oil supplied to any one area.

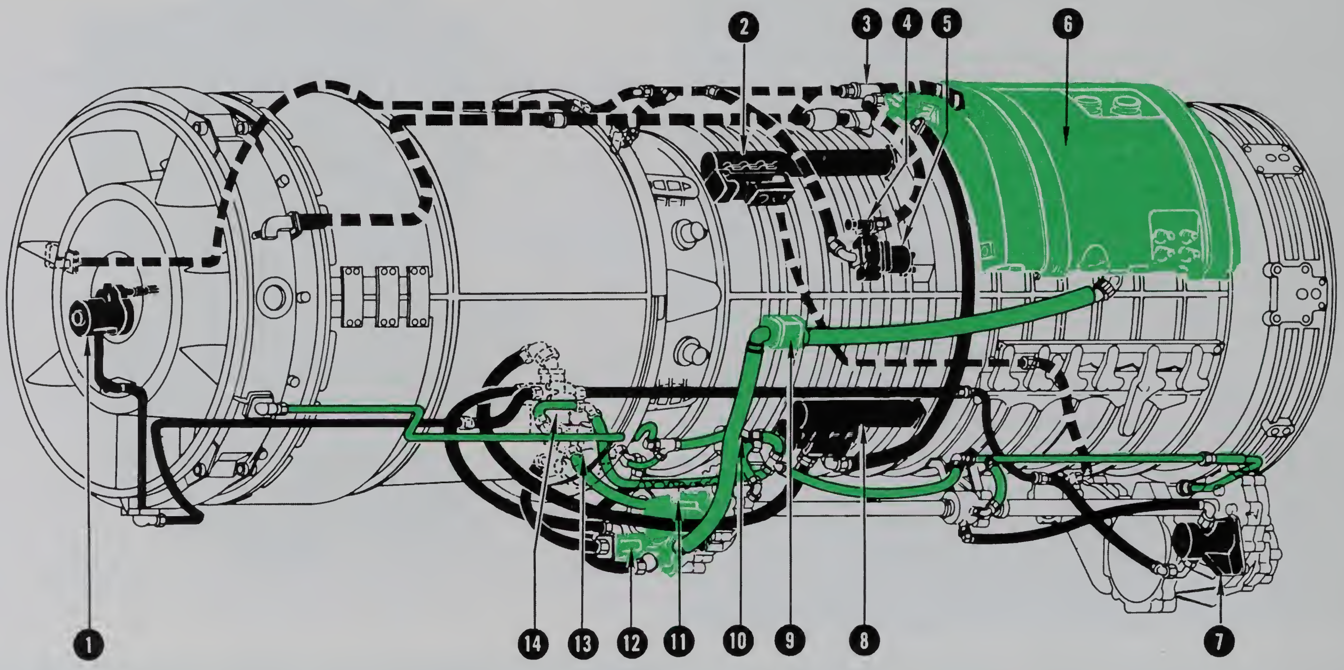
During all flight attitudes, scavenge oil from the No. 1 bearing sump and the front gearbox drains through the No. 5 compressor front frame strut to the transfer gearbox and is returned to the oil tank by one element of the transfer gearbox scavenge pump. The scavenged oil then flows from the horizontal transfer shaft damper bearing to the second element of the transfer gearbox scavenge pump. Both elements discharge to the scavenge filter.

The rear gear box scavenge pump is a three-element type with each element inlet independent of the other. One element scavenges oil from the bearings and gears in the rear gear box; another element scavenges oil which flows through the No. 6 strut of the compressor frame from the "dive" sump of the No. 2 (thrust) bearing. Oil from the "climb" sump of the No. 2 bearing flows through the No. 5 strut of the compressor rear frame and into the third element of the scavenge pump and, as in the other two elements, the discharge oil is routed to the scavenge filter. Another pump, a two-element, shaft-driven type, is used to scavenge the "climb" and "dive" sumps of the No. 3 bearing. The scavenged oil is pumped through the No. 5 turbine frame strut and routed to the scavenge oil filter.

After the engine oil passes through the scavenge oil filter, it is directed into the engine fuel/oil cooler. Here the oil is cooled by the engine fuel which flows through the core of the cooler. At oil inlet temperatures below 100°F, a pressure relief valve opens and bypasses the oil around the cooler core. A fuel temperature sensor opens the oil bypass valve when fuel temperatures reach 241°F, because the fuel cannot safely absorb additional heat from the scavenge oil. Then the scavenge oil is returned from the cooler to the engine compartment of the oil tank, where entrained air is separated from the oil, rendering it ready for re-use.

Ordinarily, oil flows through the inlet port and into and out of the engine fuel/oil cooler. If, however, the temperature of the scavenge oil falls below 38°C (100°F), the pressure drop across the oil bypass valve will then be sufficient to compress the oil bypass valve spring and force the valve from its seat. A portion of the oil then bypasses the cooler core and flows through the bypass to the outlet. As the temperature of the oil increases, the pressure drop across the valve decreases and the oil bypass valve closes, forcing all the oil through the cooler core, after which it returns to the engine compartment of the oil tank.

Linked to the fuel/oil cooler shutoff valve is a fuel temperature sensor. When the fuel temperature reaches 117°C (241°F), a thermostatic element of the



Lubrication System in Relation to CJ805-3 Engine

sensor expands, tending to close the shutoff valve. The resulting increased pressure differential across the oil portion of the cooler opens the oil bypass valve and the oil flows through the bypass port of the oil outlet. Enough oil is bypassed to prevent the discharge fuel temperature from exceeding 124°C (255°F). The maximum pressure drop across the fuel portion of the cooler is 50 psi at a flow of 15,000 pph.

The sump pressurizing subsystem regulates the head of air pressure on oil in the tank, oil in the accessory case gearboxes, and oil in the bearing sumps. This assures proper operation of the supply and scavenge pumps under varying altitudes and operating conditions. Compressor air, bleeding across the bearing seals and into the bearing sumps, pressurizes the bearing sumps and the three gearboxes. These areas are manifolded together and vented through a check valve into the oil tank and to the tank pressurizing valve. An orifice in the tank pressurizing valve bleeds off any excess air pressure above that which is required to establish a system pressure of 3 to 4 psi above ambient pressure. Excess air is bled overboard through a vent in the valve where a check valve within the tank pressurizing valve is used as a relief valve for momentary pressure changes.

Under some conditions, air must be supplied from an outside source, and discharged into the sump areas through the check valve in the sump pressurizing valve. The air is scavenged with the oil and routed to the oil tank where the entrained air is separated from the oil and the excess air is vented either to ambient or back into the sump areas. An additional check valve allows excess sump pressurizing air to bleed into the oil tank but restricts flow in the opposite direction. At certain engine operating conditions, the sump pressure decays much faster than tank pressure. This check valve prevents the higher pressure in the oil tank from forcing oil backwards across the bearing seals.

Aspects of the lubrication system of particular interest from a design limit standpoint are listed in the lubrication system limits table. Two limits are shown — normal and extreme. *Normal* range defines the range encountered during normal operation; *extreme* range defines a range that may be encountered less than 5% of the operating time.

LUBRICATION SYSTEM LIMITS

1. Lube Oil Temperature into Engine as High as:

Normal Range	100° to 250°F (38° to 122°C)
Extreme Range	—40° to 300°F (—40° to 149°C)

2. Lube Oil Temperature out of Engine:

Normal Range	150° to 300°F (66° to 148°C)
Extreme Range	—40° to 350°F (—40° to 177°C)

3. Lube Oil Pressure:

Normal Range	12 psig minimum at Idle rpm
Normal Range	35 to 60 psig at Max rpm with oil in at 135°F
Extreme Range	30 to 500 psig at 100% rpm (gage limit 200 psi)

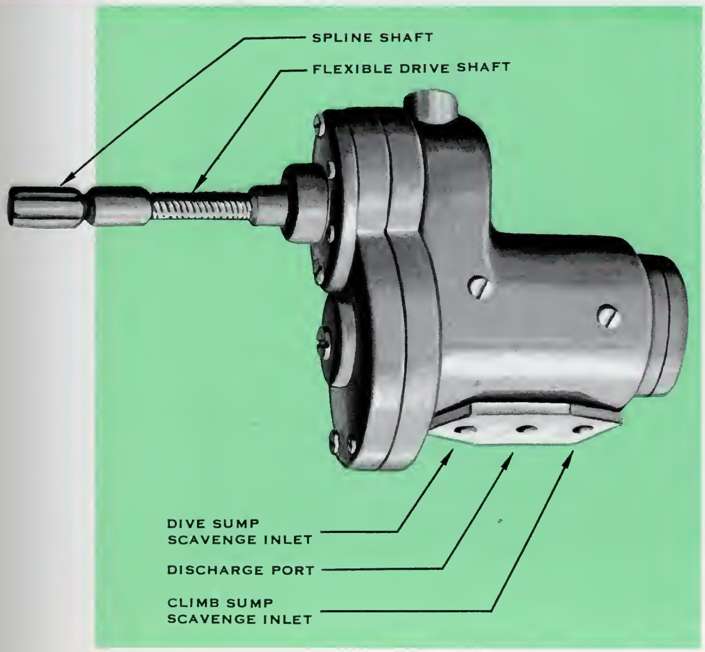
It is interesting to note that immediately following engine starts, after prolonged soak periods in cold weather, supply oil pressure can range as high as 500 psig before the oil begins to warm up. The pressure indicator on the flight engineer's panel, however, reads only as high as 200 psig, which is the gage limit. The oil pressure tap, located at "5 o'clock" on the compressor rear casing, contains two calibrated orifices which work with a pressure relief valve to protect the oil pressure transducer from extreme pressure surges.

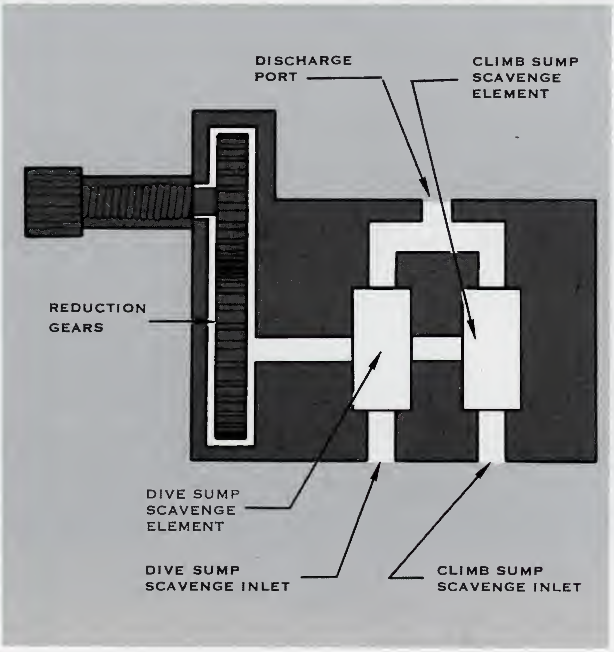
There is an engine oil pressure indicating system which consists of a synchro type oil pressure transmitter and synchronous indicator. The transmitter is mounted at the engine rear gear box oil pressure port, and the indicator is installed on the flight engineer's instrument panel. The oil pressure, entering directly into the transmitter through an orifice, actuates a differential pressure sensing unit used to position a synchro-motor assembly. This assembly, in turn, remotely positions a pointer on the indicator. The system is duplicated for each engine and is operated by power from the single-phase, 400-cycle, a-c essential bus.

An oil-low-pressure warning system is incorporated in conjunction with the oil pressure indicating system. It consists of an oil pressure warning light on the pilot's master warning panel and a pressure switch, line-mounted, adjacent to the engine rear gear box. The pressure switch is set to illuminate the warning light when the pressure drops to 9 ± 1 psig and to extinguish it when the pressure increases to 12 psig or above. Mounted on the flight engineer's panel are four dial indicators that reflect the oil temperature of each engine. Each oil temperature indicating system consists of a temperature bulb, located in the return line between the oil scavenge filter and oil cooler, and the indicator. The bulb acts as part of a bridge circuit in the indicator, causing an unbalaced condition in the circuit which in turn is reflected in degrees of temperature on the indicator dial.

There are four oil quantity indicating systems, one for each engine. They consist of capacitance-type electronic bridge circuits that indicate the quantity of oil in gallons in each engine tank. These are in addition to the direct-reading dipsticks described earlier. Each of the electronic indicating systems use 115-volt, 400-cycle, a-c power from the No. 3 essential a-c bus. A capacitor probe is installed in each engine oil tank and an amplifier unit is installed in the electronic compartment with the quantity reading gages mounted on the flight engineer's panel.

Scavenge Pump



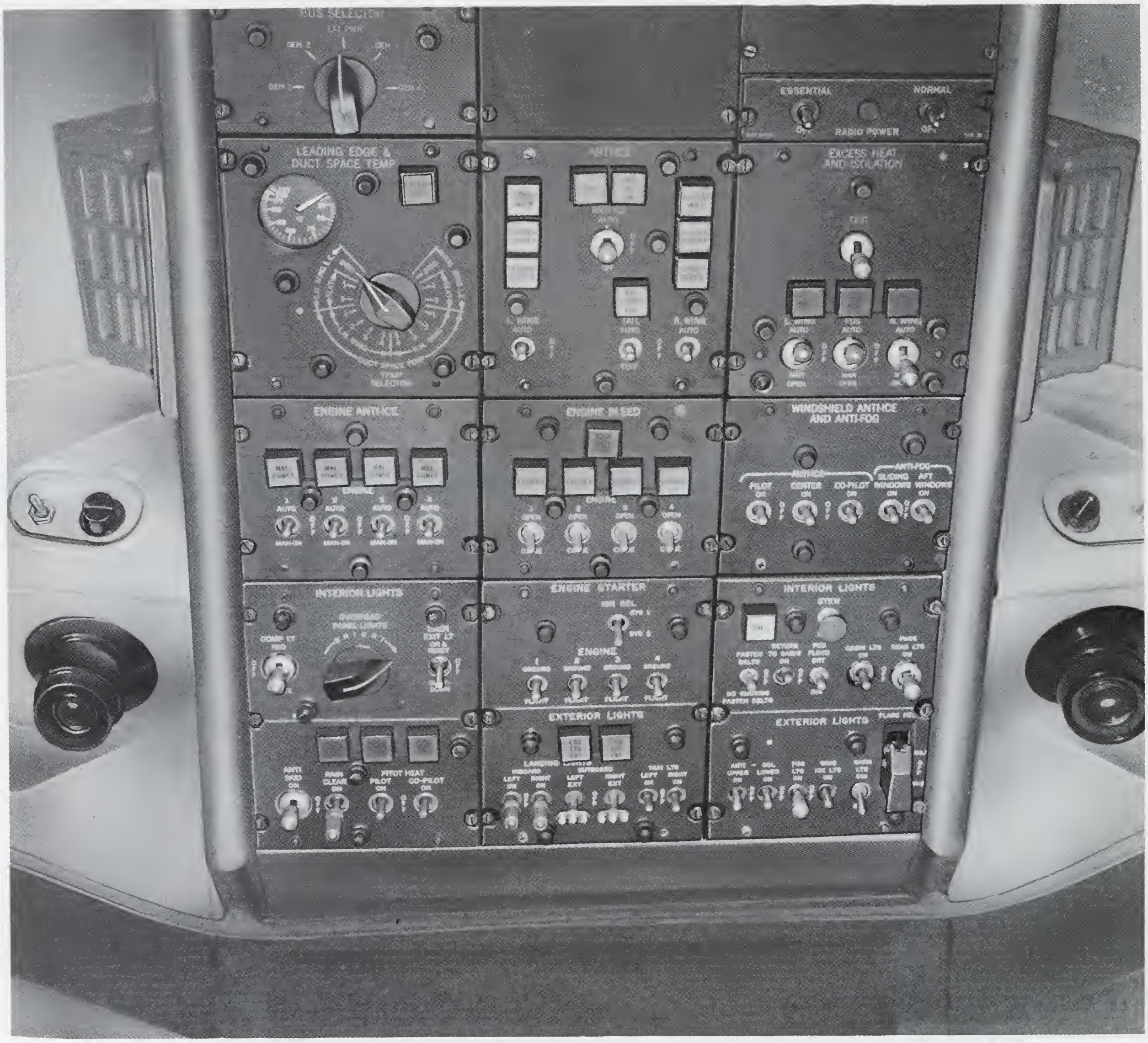


Excess Heat & Isolation System

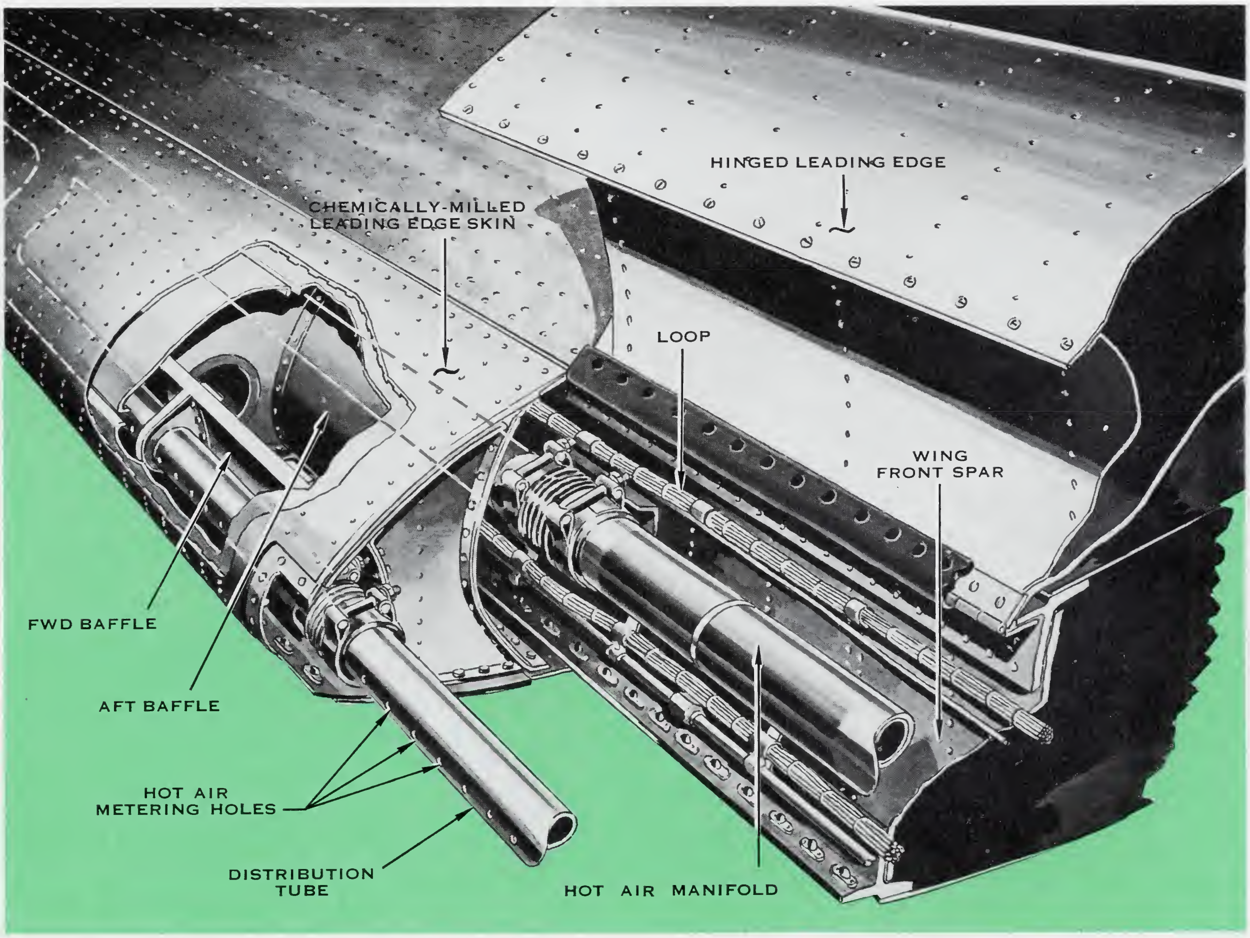
Convair 880/990

The front spar of the Convair 880/990 wing has a structural design temperature limit that must be maintained to assure integrity of the structure. Hot air, bled from the engines (used for anti-ice, rain clearing, and other systems), is routed through ducts that pass between the spar and leading edge of the wing, and in the fuselage. Under normal operating conditions, excessive heating of the spar is prevented by insulation, which covers the bleed air ducts. Should the bleed air duct insulation become damaged or develop a leak, the wing structure could become overheated, if preventive measures were not incorporated in the "880/990" design.

The safety feature, which protects the wing structure in the area of the bleed air ducts, is the excess heat and isolation system. This system consists of heat detecting loops installed in the duct spaces of 1) the wing — one loop for each wing — and 2) one loop for the fuselage. For aircraft having the pneumatically-operated refrigeration system, two loops are in the underwing area. The wing loops extend into the pylon areas. A control panel, labeled EXCESS HEAT AND ISOLATION, is located on the pilots' overhead switch panel and is fitted with EXCESS HEAT warning lights, control switches, and a TEST switch. A control box, located in the electronics compartment, consists of a relay box, and magnetic amplifier control units.



880 Controls for Ice and Rain Protection Systems



Wing leading edge section showing exhaust hot-air chambers.

The excess heat and isolation system is divided into as many sections as there are heat detection loops — the number depending on customer requirements — and monitors left wing, fuselage, and right wing. Each section has an AUTO and MAN OPEN control switch for automatic or manual operation, and an EXCESS HEAT warning light on the EXCESS HEAT AND ISOLATION panel.

If the alarm point of the wing spar sensor should be reached, one of the red EXCESS HEAT warning lights will illuminate to indicate the area of excessive heat and, if the control switch to that area is in the AUTO position, the isolation valve in the applicable duct will automatically close the bleed air flow to the area of the leak, or break.

The normal position of all switches is AUTO. If the control switch is in the MAN OPEN position during excessive heat conditions, the EXCESS HEAT warning light for the heated area will still illuminate, but the automatic protection from excessive heating will be bypassed. Without this automatic protection during excessive heat conditions, possible overheating of the wing structure could result.

The heat detecting loops have a normal impedance of more than one megohm between their inner and outer conductors. When they are heated to a temperature that reaches their alarm limit, the impedance is greatly reduced and in turn is reflected in a control winding of the magnetic amplifier which influences a signal that actuates the applicable isolation relay.

If four or more inches of a heat detecting loop is subjected to a temperature that reaches its alarm limit, it will actuate the corresponding EXCESS HEAT warning light on the EXCESS HEAT AND ISOLATION panel. With the system operating automatically, a warning from a wing section will close both engine bleed air valves on that side, and the correlative isolation valve. A fuselage section warning will close both wing isolation valves.

Wing leading edge anti-ice air flow (typical).

To prevent the loss of pressurization due to EXCESS HEAT in the fuselage section when both wing isolation valves would close (in AUTO mode), the pressurization turbocompressors are supplied from a point outboard of the wing isolation valves.

The TEST switch on the EXCESS HEAT AND ISOLATION panel is used to check out the heat detection circuits. When all the heat detectors, relays, and control units are operating properly, switching to TEST position will illuminate all EXCESS HEAT warning lights. With the test switch in TEST and the control switches in AUTO, the entire bleed air system will be isolated and will remain so until the control switches are moved to OFF and then back to AUTO or MAN OPEN positions. With the control switches in OFF or MAN OPEN, the bleed air system will not be affected. Releasing the TEST switch will extinguish the EXCESS HEAT warning lights.

The isolation control switches are normally in the AUTO position. When an EXCESS HEAT warning light illuminates, it indicates the section of excessive heat, and isolation of that section automatically goes into effect. A check for the proper isolation of the indicated overheated section can be made by moving the corresponding control switch to the OFF position. If the temperature is back to normal, the EXCESS HEAT light will go out; if the section is still overheated, the light will remain on.

The temperature of the wing duct spaces may exceed the heat detector alarm limits during ground engine run-up with high bleed air flows, because the alarm temperatures are based on in-flight conditions, where ram air cooling is present. Therefore, isolation and warning systems for the left- and right-hand wings are rendered inoperative through an interlock, whenever the landing gear ground safe relay is energized. This feature prevents the excess heat isolation system from cutting off the bleed air supply erroneously while the airplane is on the ground.

Manual override of the isolation valves is used, should the "DUCT SPACE TEMP" light go on while the isolation system is locked out on the ground.

all weather protection

CONVAIR 880/990

ENGINE AND NACELLE TESTS
MT. WASHINGTON, N. H.

anti-ice, anti-fog, rainclearing

Rain, snow, and ice are transportation's ancient enemies. Flying has added a new dimension, particularly with respect to ice. At the high speeds of new jet transports, under certain atmospheric conditions, ice can build rapidly on airfoils and air inlets.

Three means to prevent or control ice formation are commonly used in aircraft today: 1) heating surfaces by hot air, 2) heating by electrical elements, and 3) breaking up ice formations, usually by inflatable boots. A surface may be "anti-iced," either by keeping it dry by heating to a temperature that evaporates water upon impingement; or by heating it just enough to prevent freezing — maintaining it "running wet"; or the surface may be "de-iced" by allowing ice to form and then removing it.

All of these means are utilized in providing icing protection for the Convair 880 and 990 aircraft. Under icing conditions, wing surfaces and engine inlet ducts are heated by engine bleed air to vaporize any moisture on contact. Engine inlet struts and guide vanes, and the windshields, are maintained running wet — the struts and guide vanes by bleed air, the windshield by electrical heating and the empennage by electrical de-icer boots.

Bleed air is ducted to the base of the windshields and directed across their external surfaces to keep them clear of rain. By means of a low-density electrically heated coating, the inner windshield panels are kept warm enough at all times to prevent interior fogging.

Empennage leading edges are electrically de-iced. Instrument pitot intakes, the "Q" intake for the rudder feel cylinder, the elevators, and an underwing ventilating scoop for the wing front spar passageway, are kept from icing by electrical heating elements. The "Q" intake heater is energized whenever electrical power is on the airplane.

Control switches for all the systems are located on the pilots' overhead panel. Windshield anti-fog, rain-clearing, and pitot heat must be turned on manually. Windshield anti-ice coatings, tied into the ice detector circuit on the 880M, operate automatically. Engine inlet, wing, and tail systems may be turned on manually or the panel switches can be set for automatic operation on the 880M. Overheat of the wing and tail systems in ground automatic operation is prevented by routing the circuitry via a ground safety switch activated by the main landing gear.

On the 880M, during normal operation, the controls are set for automatic anti-ice and de-ice before takeoff. Then, the systems will be energized when ice is sensed by the detector system.

The detectors are pairs of impact pressure probes mounted in the engine inlet duct. Each probe has a series of small holes in its forward face, and smaller ones in the aft face. One of each pair is constantly heated by an electric element, so that ice will not form on it. When the airplane encounters icing conditions, ice will form quickly and plug the holes on the second unheated probe. The differential in ram air pressures between the two probes triggers an electric contact on the 880M, operating relays that energize the anti-icing systems for engine, wing, windshield, tail, and front spar ventilating scoop. On the "990," relays energize an ice light (red), making it necessary to manually turn on adverse weather systems.

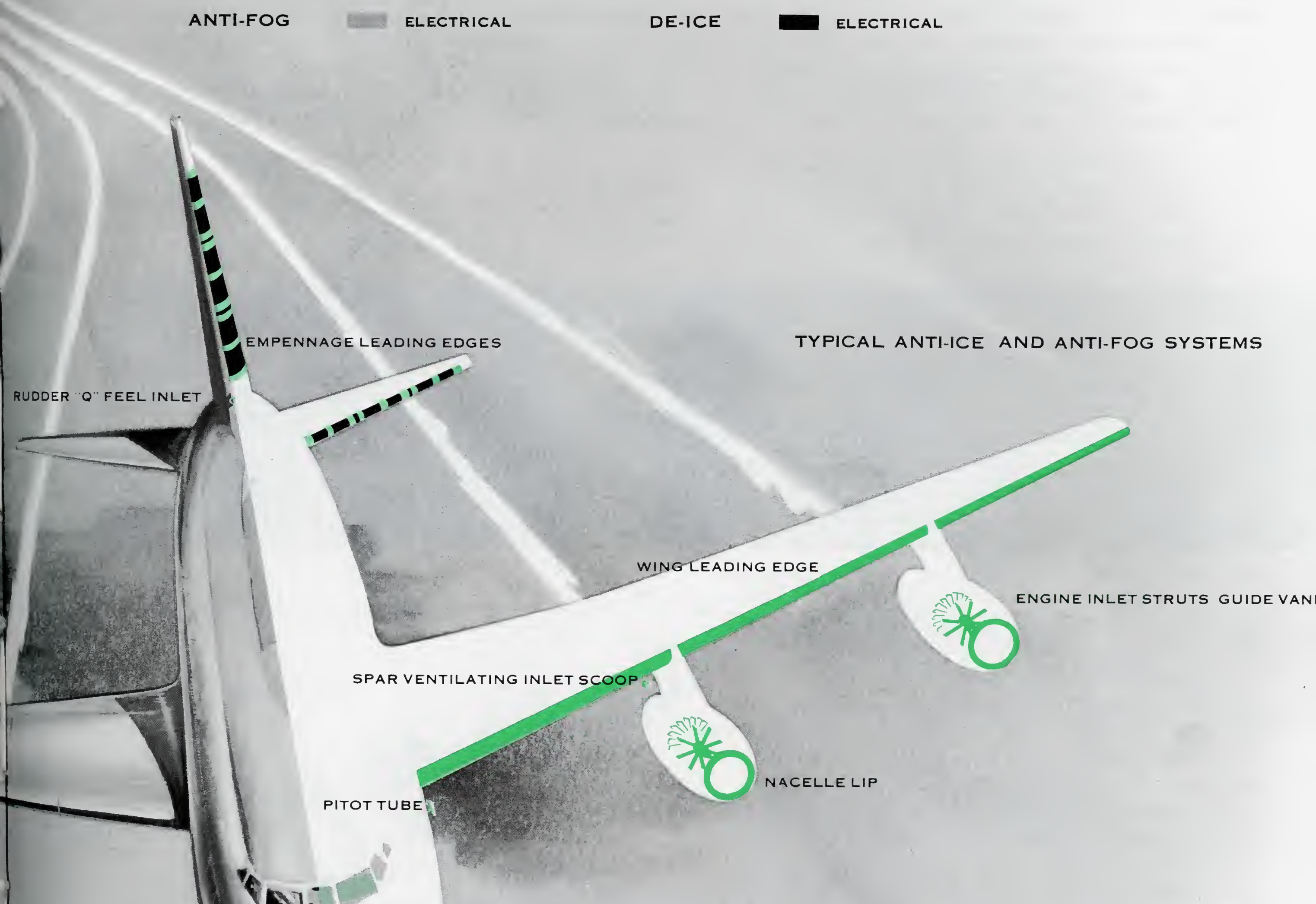
engine and nacelle anti-ice

The strut and inlet vane anti-icing systems are part of the engine assembly. Seventeenth-stage bleed air is taken directly from a port on the aft compressor frame and is ducted forward to the two horizontal and two 45°-up struts. A solenoid-operated pressure regulating and cutoff valve, opened by the detector interpreter signal or by a manual switch, maintains a maximum pressure of 20 psig downstream of the valve. The bleed air path is through the four struts into a manifold, and outward through the four other struts and through the 20 inlet guide vanes, discharging into the engine inlet air flow.

From the manifold, air is also ducted forward into the nose cone fairing — "bullet-nose." Flow is directed to the fairing nose and aft through a corrugated-type double skin, discharging at the base into the airstream.

Struts, vanes, and nose cone are maintained running wet under all icing conditions.

Air for anti-icing the nacelle lips is tapped from the bleed air distribution duct. A solenoid-controlled pneumatically-actuated valve regulates pressure to approximately 13 psig. The flow is to a modified "D" ring around the leading edge, and aft through a double skin to discharge ports on the inside surface



of the duct lips. The passages are chemically milled, with half-inch-diameter bosses for attachment of the inner skin, leaving a narrow-gap high-efficiency passage for the hot air.

The "990" has two inlet duct fairings, one at the forward end of the nacelle and a second inner fairing that divides airflow between compressor and aft fan. Anti-icing in both is similar to that already described, except that piccolo tubes, with a common bleed duct. supply both sets of lips, plus the islands and splitters that separate the inner and outer lips.

wing anti-ice "880 M" & "990"

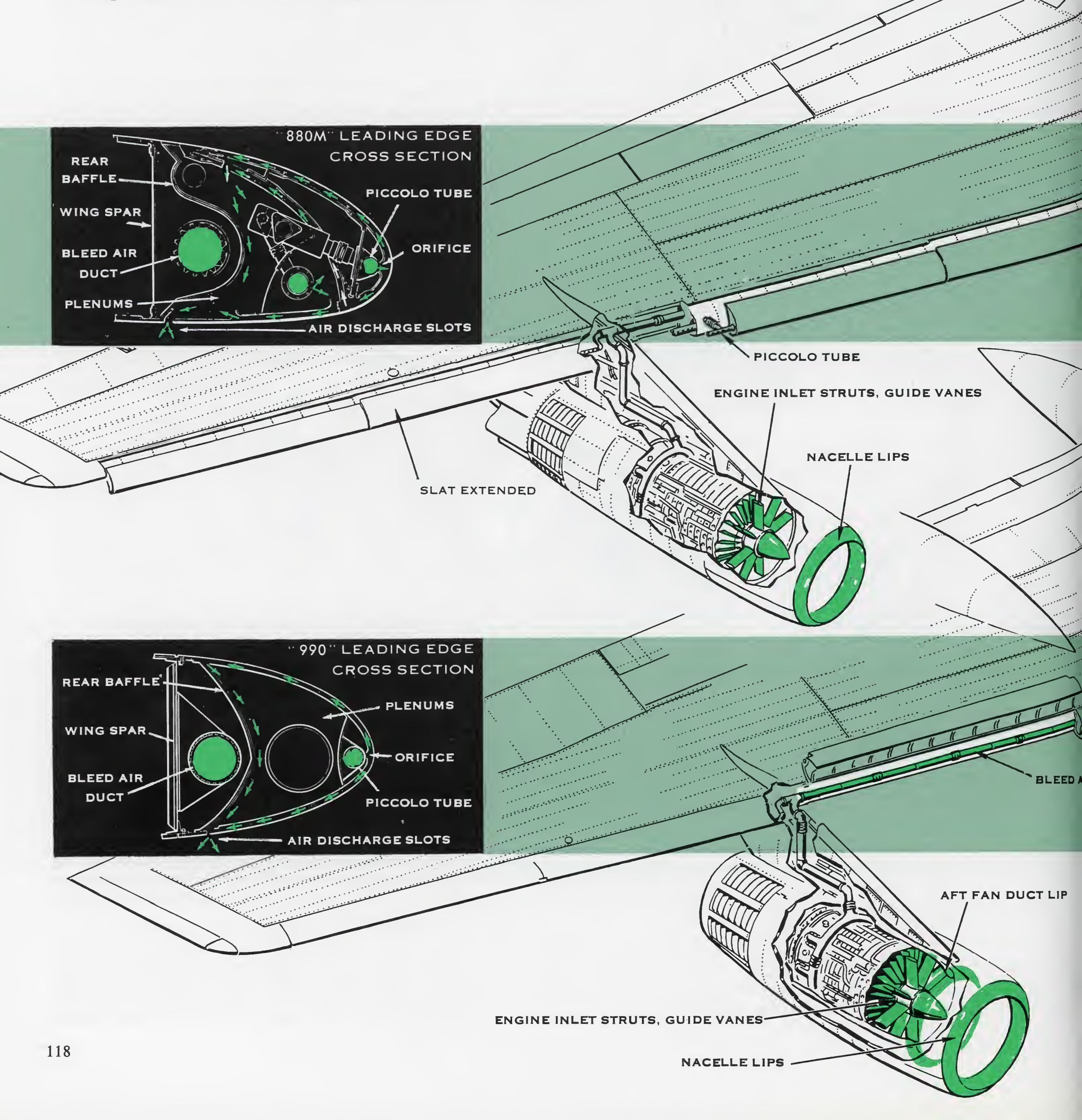
The inboard wing is protected by a double-skin hot air anti-icing system in the leading edge, forward of the front spar. The main bleed pressure regulating valves, between each engine bleed air manifold and the main bleed air ducts, reduce pressure to 40 psig in the main duct. Air is ducted to the inboard wing section through valves, that further reduce pressure to approximately 13 psig.

The ducts feed piccolo tubes. Baffles aft of the piccolo tubes make the forward portion of each leading edge section a plenum for the piccolo tube air distribution. The inner surface of the outer skin

of the leading edge is chemically milled in chordwise strips, approximately 1¾ inches wide and 0.040 to 0.050 inch deep, separated by .350-inch-wide strips for attaching the inner skin. This passage, with a high thermal efficiency, is designed to use up to 95% of the initial heat energy of the air.

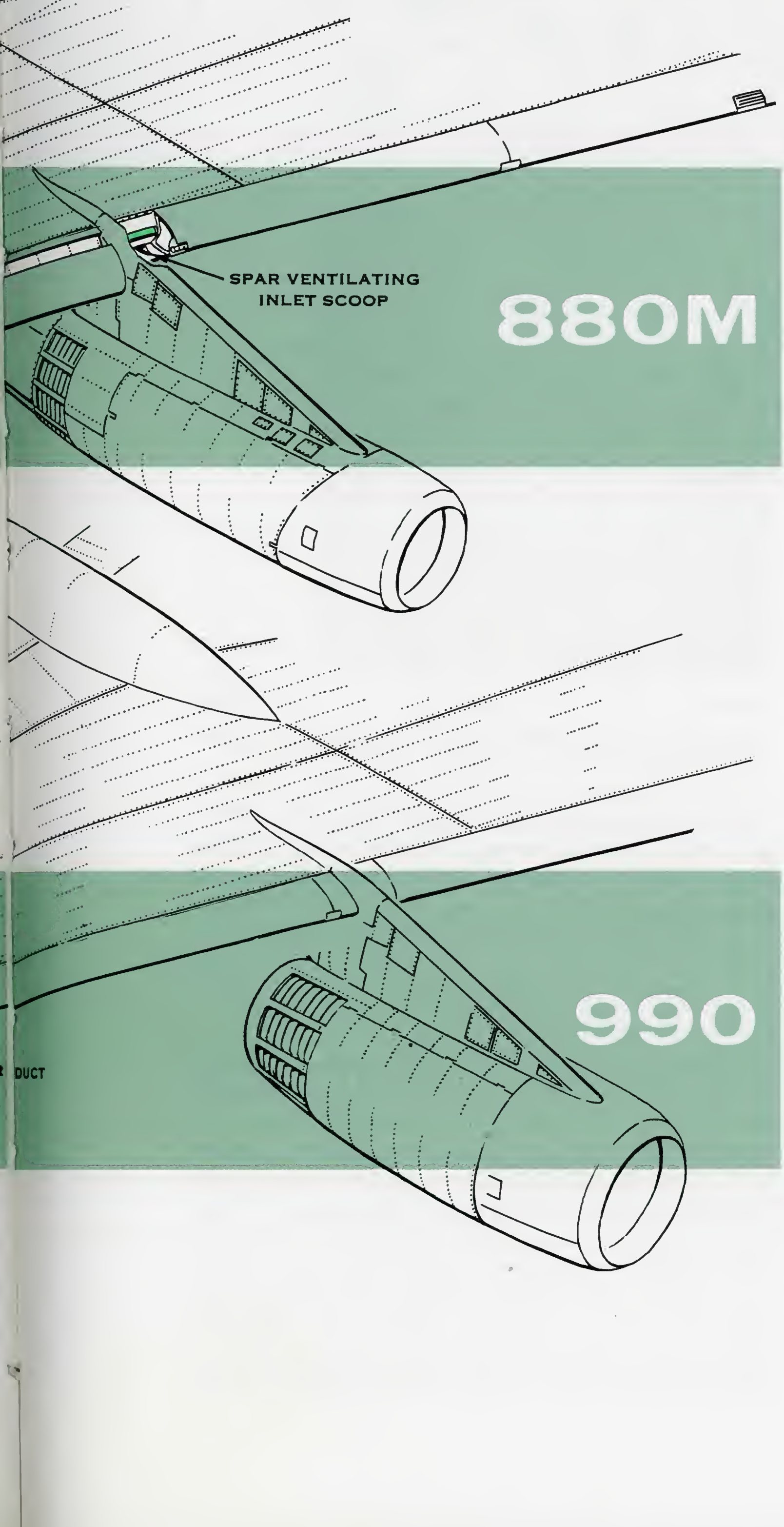
A Fiberglas baffle separates the main bleed air ducting from the forward piccolo plenum, forming a discharge plenum. The air flows from the chem-milled passages into the discharge plenum and is vented overboard through underwing slots. Back pressure from the underwing slots keeps air pressure in the leading edge approximately two psig above ambient.

The area between wing spar and rear baffle, through which the bleed air duct runs, is ventilated by ram air introduced through a flush inlet on the wing lower surface inboard of the inboard pylon. This inlet scoop is anti-iced by an electrical heating element.



The slats are flap-like airfoils that in ordinary flight form the wing leading edge, but extend forward and downward for increased effective lift at low speeds. With slats extended, the airstream flows through the slot between leading edge and slat; therefore, the leading edge behind the slot must be anti-iced, as well as the slat itself.

The leading edge is anti-iced with hot air flowing through chem-milled passages in the outer skin. The slat itself is anti-iced in the same manner: bleed air flows through a telescoping duct into a piccolo tube in the lower, forward portion of the slat, which is isolated from the rest of the interior by a baffle. The outer skin is chem-milled to direct air aft into the rear space, whence it discharges into the slipstream.



empennage de-icing

Several considerations determined the choice of the cyclic electrical system employed in the empennages of the "880" and "990" aircraft. Utilizing an electrical rather than hot-air system eliminated the need for ducting bleed air aft through a 90-foot length of the fuselage. However, an electrical evaporative system is impractical, because of the amount of power required; and a running-wet leading edge is undesirable because of freezing of runback. Therefore the empennage is de-iced rather than anti-iced.

The system in the "880" and "990" empennages may be described as de-icing in segments. Leading edges of the left-hand and right-hand horizontal stabilizer, and of the fin, are each divided into six areas. The 18 areas, each approximately three feet long, are de-iced in sequence once every three minutes by electrically-heated blankets in the skin. De-icing sequence is from tips to fuselage — left-hand stabilizer tip, right-hand stabilizer tip, vertical tip, then the next three inboard sections, and so on.

The heating blankets consist of .003-inch ribbons, sandwiched between .012-inch layers of resin-impregnated Fiberglas. An outer stainless steel .005-inch skin is bonded to the heating blankets, and the blankets are bonded to an .025-inch aluminum inner skin. Power supply is three-phase 200-volt line-to-line a-c from the No. 2 essential load bus. Each heating blanket has three circuit elements, one for each phase. Power is switched from one blanket to another by a control unit.

Between blankets are 1-inch-wide parting strips that are continuously heated to prevent ice formation. This separates ice accretions into blocks. When the skin under the block is heated, it melts a thin layer of ice, separating the ice block from the wing surface. Since empennage leading edges have approximately 40° sweepback, the aerodynamic forces are sufficient to remove the accumulation.

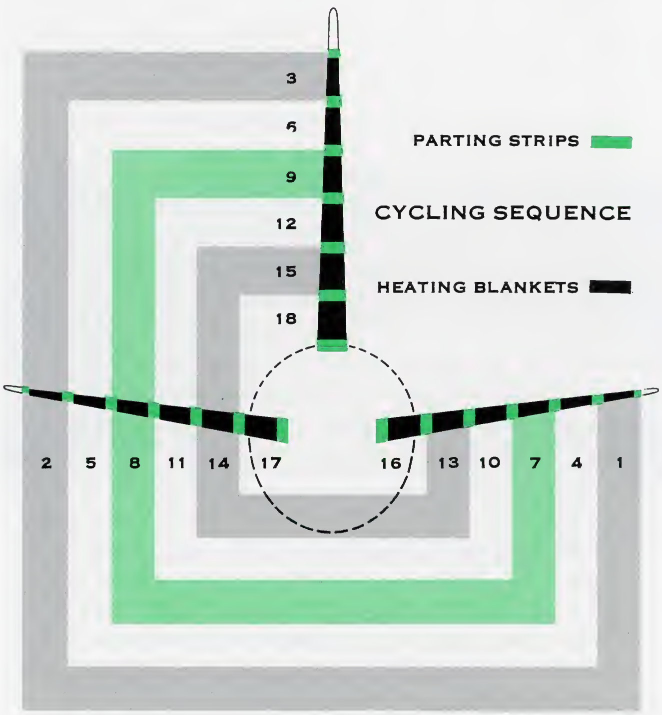
One of the requisites of a de-icing system is that enough ice must be permitted to collect for good shedding. Detailed studies and tests determined that three to four minutes is the best interval for de-icing. That much time allows sufficient buildup without causing too much drag. Therefore, the system is set to cycle once each 3 to 3½ minutes, allowing 12 seconds maximum for each blanket area.

The time required for de-icing each area usually varies from 1 to 10 seconds. However, if the area is de-iced within 2 seconds, for example, continued application of heat would have the undesirable effect of keeping the area above freezing for another half minute or so, and during this time the intercepted water could run back and refreeze. To prevent this, a temperature sensor is imbedded in each cycled area. When the surface temperature reaches 50° to 60°F, the control cuts power to that area and switches to the next. After all 18 areas have been heated, there will be a "dwell" period long enough so that 180 seconds will elapse between cycling.

If the temperature cutoff point is not reached within 12 seconds, the controller will switch to the next section. The controller also provides circuit overload protection; if one heating element is shorted out, the controller will disconnect that area and proceed to the next.

The parting strips operate at low heat on single-phase current. Overheat is rarely a problem; neverthelesss, thermal switches are mounted on the aft side of the left-hand inboard stabilizer strips, to cut off power at a temperature of 90°F. A short-circuit in one strip would cut off one phase of the three-phase current supply, leaving two-thirds of the areas with parting-strip heat.

The total power requirement for empennage de-icing is from 7.38 to 9.22 kva for the cycled elements, and from 2.5 to 3.15 kva for the parting strips. The primary electrical circuit is routed through a ground safety switch, so that it cannot be operated on the ground.



windshield anti-ice, anti-fog and rainclearing

There are seven multi-layered glass panels in the flight compartments of the "880" and the "990" airplanes: a center windshield, two main windshields directly ahead of pilot and copilot, and a sliding window and aft window on each side.

All of these have three glass plies separated by vinyl plastic. The main windshields, for example, have an outer ply .187 inch thick, an .080-inch layer of vinyl, a .312 center glass ply, a second vinyl layer .300 inch thick, and an inner .312-inch glass ply.

Only center and main windshields are anti-iced; sliding and aft windows are at such an angle to the airstream that droplets are not likely to strike the surface. The entire areas of the center windshield, and the major portion of the main windshields, are heated by a high-density electrical coating on the inner surface of the outer ply, keeping the windshield running wet under all flight icing conditions.

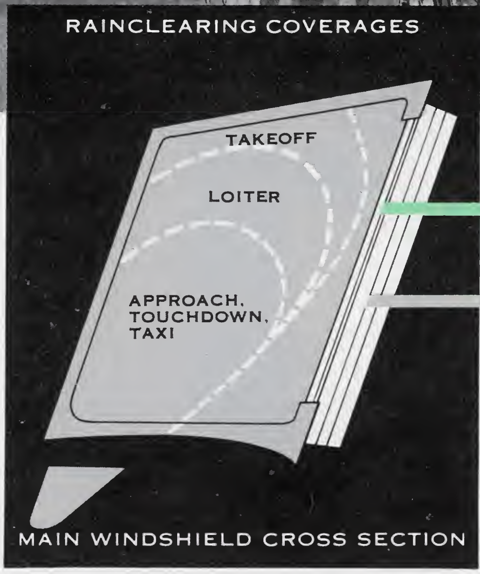
The entire areas of center and main windshields, and most of the sliding and aft panel areas, have a low-density coating on the inner surface of the center glass ply, which maintains the inside surfaces at a temperature above the flight deck dewpoint.

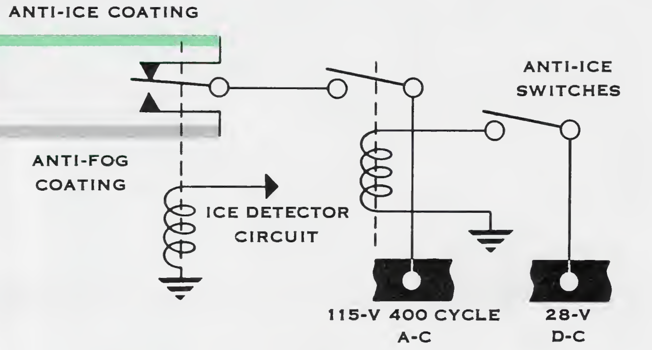
Control switches for windshield anti-fog are on the overhead panel. In the typical "880" panel illustrated, all five switches — three ANTI-ICE and two ANTI-FOG — are normally turned on at takeoff. This energizes the anti-fog coating in all seven windshields. When icing is encountered on the 880M, the automatic detector system deactivates anti-fog and activates anti-ice in center and main windshields, regardless of the position of the main switch in the ANTI-ICE panel.

An important reason for having anti-fog activated is that warming the vinyl layer adds materially to the ultimate yield strength of the windshield. In the event of a bird strike, the vinyl supplies the plasticity and resilience to make the windshield shatterproof and to insure against sudden cabin decompression. The effectiveness of the vinyl is greatest at 90° to 100°F, the temperature which the anti-fog coating maintains.

Temperature sensors imbedded in all windshield coatings allow external controllers to maintain the desired temperatures on all windshields.

The "880" and "990" utilize an airblast rainclearing system that was first developed by Convair for F-102 interceptors and has now been proved in service over several years of all-weather operation. Bleed air is ducted to the lower forward corners of pilot's and copilot's windshields and released through nozzles that direct a flat, high-velocity flow across the outer surface. The air blast forms a barrier that prevents raindrops from striking the windshield surface.





ANTI-ICE, ANTI-FOG SIMPLIFIED SCHEMATIC

control and indicating systems

When the airplane enters icing conditions, the first detector probe signal illuminates the blue ANTI-ICE ON light on the center panel. Then, if any anti-ice switch is not in automatic position, the red ICE light illuminates to warn the pilot.

On the 880, with the switches of the ANTI-ICE and ENGINE ANTI-ICE overhead panels in AUTO position, all airplane anti-icing protection will be automatic. The ANTI-ICE switch has an ON position which bypasses the detector system. This ON position is useful principally for ground check of the separate systems on that panel. The TAIL switch TEST position allows cycling of the control unit. The ENGINE ANTI-ICE switches have an ON position that overrides the automatic detection or automatic cutoff control systems.

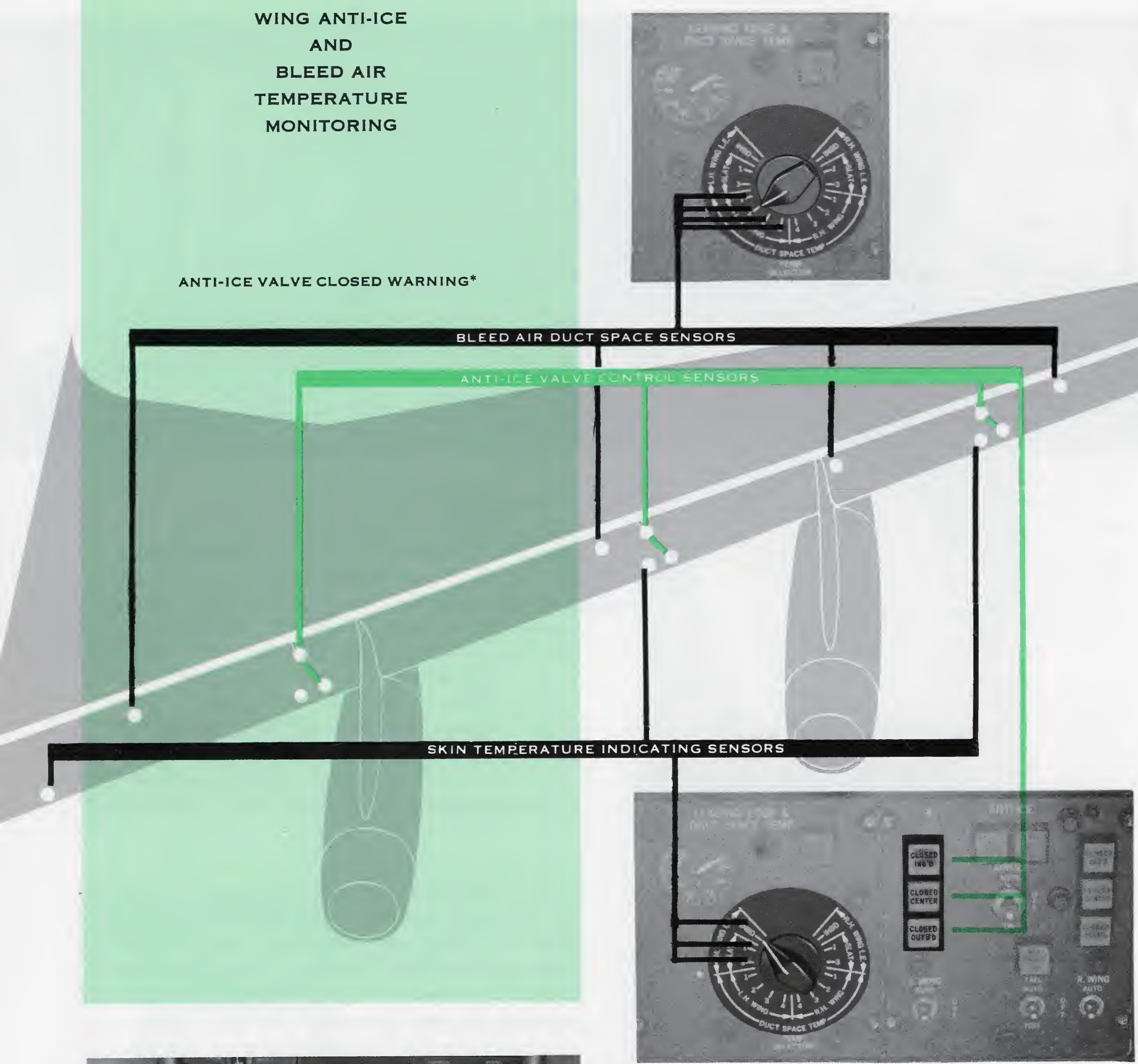
Should any wing anti-ice valve remain closed when it is supposed to be open, a malfunction switch in the valve illuminates the appropriate wing-position CLOSED light in the ANTI-ICE panel. ENGINE ANTI-ICE panel CLOSED lights illuminate when engine anti-ice bleed air valves remain closed in spite of a signal to open. Malfunction lights are provided for the empennage de-icing system.

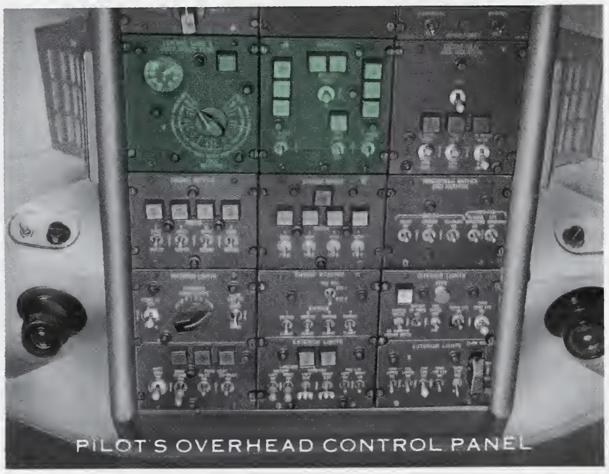
Operation of the wing anti-ice system utilizes several interrelated electrical circuits. The engine air and anti-ice circuit provides an ice signal and master control of anti-icing; the bleed air and excess heat and isolation circuits control the main bleed air flow which furnishes hot bleed air for ice removal, and the wing anti-ice circuit directly controls the flow of bleed air to the distribution tubes.

Temperature sensors give primary protection to the leading edge skin and wing slats. The sensors are connected to anti-ice overheat valve control box that monitors control of the corresponding wing anti-ice shutoff valves. The temperature sensors close the shutoff valves when:

1. The skin temperature of the LH and RH inboard leading edges rises to 330°F (165.6°C).

WING ANTI-ICE AND BLEED AIR TEMPERATURE MONITORING





PILOT S OVERHEAD CONTROL PANEL

2. The skin temperature of Nos. 1 and 3 slats rises to 300°F (149°C).

When the skin temperature recedes to 115°F (46.1°C), the shutoff valves open to permit further heating.

Anti-ice bleed air shutoff valves, like those of the other bleed air systems, are spring-loaded toward the closed position, so that if electrical power is cut off from the solenoid or operating motor, the airplane will not be subjected to uncontrolled heat or pressure. Electrical circuits are protected by circuit-breakers, thermal cutoffs, and overvoltage and overcurrent sensors in the control boxes.

AIR CONDITIONING and PRESSURIZATION SYSTEM for the CONVAIR 880

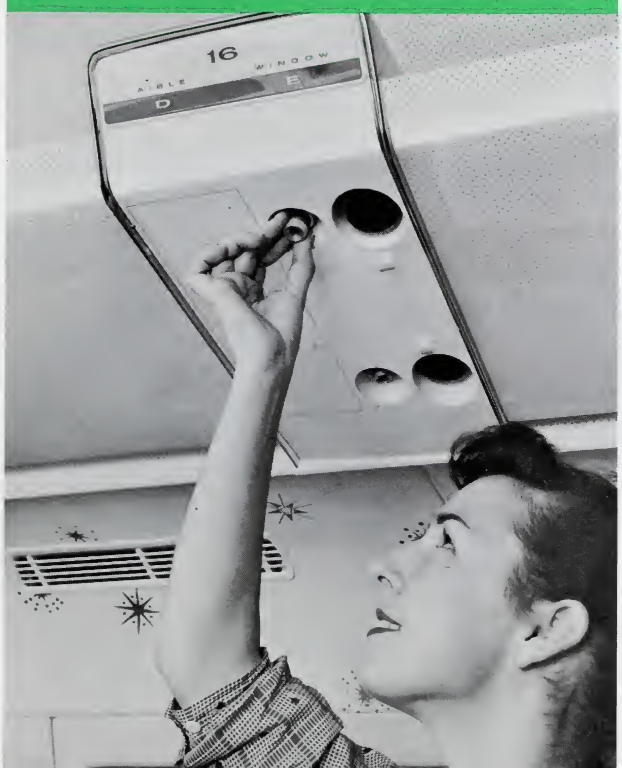
The Convair 880 air conditioning and pressurization system is designed to supply all occupied compartments of the airplane with an air flow of 160 pounds of air per minute at sea level, and 120 pounds per minute at 35,000 feet.

The air conditioning system supplies circulating fresh air, automatically heated or cooled as conditions require. A complete change of air is delivered to the cabin every 2½ minutes and to the flight deck every minute.

The cabin temperature control can maintain a temperature of 75°F in flight under all ambient temperature conditions, and a maximum of 80°F on the ground. At all outside air temperatures . . . whether 100°F or —40°F . . . the air conditioning system keeps passengers comfortable without unpleasant air surges or annoying drafts.

Each passenger has a silent individual cold-air inlet to provide direct airflow, if desired. All air entering the cabin through the main outlets below the hatracks is discharged through side panel floor exit ducts, and then is dumped overboard.

Individually-controlled cold-air inlets provide direct air flow as desired.



Heating and cooling of baggage compartments, and electrical and electronic equipment is also provided by the air conditioning system.

The Convair 880 holds a sea level cabin altitude up to an airplane altitude of 21,300 feet, and an 8000-foot cabin altitude up to an airplane altitude of 41,000 feet. The normal cabin differential operating pressure is 8.3±.10 psi. In event of failure to both cabin pressure regulator sections of the outflow valves, the relief valves will relieve at a differential pressure of 8.50±.10 psi. Signal lights on the flight deck control panel will indicate the respective valve closed position. A warning light will illuminate whenever cabin altitude exceeds 10,000 feet.

Presetting of the rate of change of cabin pressure control permits operating at rapid rates-of-climb and descent with a minimum rate-of-change of cabin altitude. Flow is maintained automatically against all normal loads imposed upon the system by the ever-changing demand for pressurization and ventilation.

Surges in the cabin pressure altitude during takeoff or landing will not exceed the normal regulated rate-of-change by more than 150 fpm. The cabin pressurization system will prevent negative cabin differential pressures in excess of 10 inches of water, at airplane rates of descent of 25,000 fpm with the normal cabin air source shut off. The cabin pressurization system will accommodate a rate-of-climb of 5500 fpm and a rate-of-descent of 7000 fpm, while maintaining cabin pressure schedule tolerances.

The rate of cabin pressure change is selectable from 2000±200 fpm to 65±35 fpm. The nominal calibration is 500 fpm ±10 per cent. Deviation from selected cabin pressure rate-of-change during transient conditions will not be greater than ±25 fpm.

The basic air conditioning system is composed of two separate and independent subsystems, pneumatically-driven by bleed air from the four CJ-805 engines. Each subsystem consists primarily of a ram air turbocompressor (bleed air turbine-driven compressor), an air-to-air heat exchanger, and a vapor cycle Freon refrigeration unit.

An electrically-driven vapor cycle Freon system is available as an optional installation. This system is basically the same as the pneumatic-drive system except that the freon condenser fan and compressor are driven by an electric motor. Also, in the electrically-driven system, an electric heater is employed in the cabin and flight deck main distribution line for ground heating.

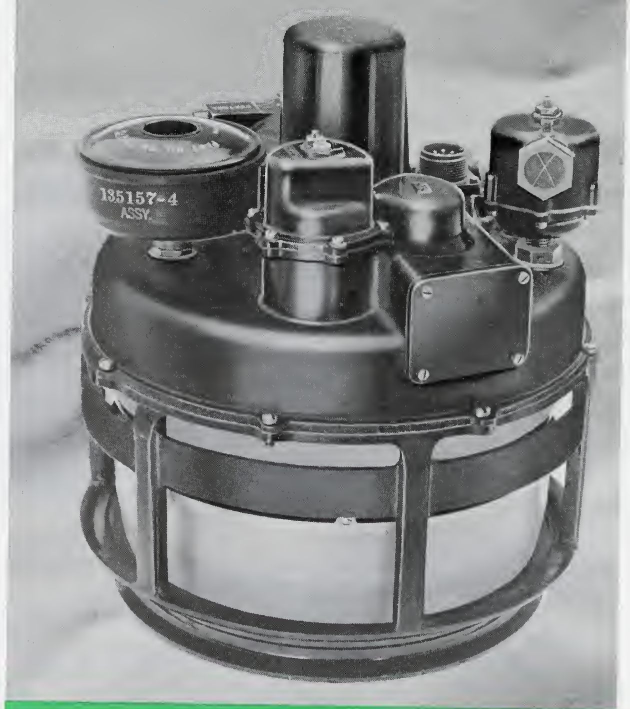
Under normal operation, in either the pneumatic or electrically-driven systems, one subsystem supplies the air for the cabin, and the other supplies air for the flight deck. Each subsystem is controlled separately, but if one subsystem fails, the other will supply adequate air conditioning and pressurization for both the cabin and flight deck for the continuation of the flight.

A vapor cycle Freon system provides full cooling in flight without increasing the load on the turbocompressors that provide the cabin pressurization and ventilating air. This becomes increasingly important in high-speed jet aircraft, because cooling is required during a greater porton of the flight regime.

The vapor cycle refrigeration unit is essentially a Freon loop system that uses Freon 114 (dichlorotetraethane), a stable, nontoxic fluid. The Freon loop contains a compressor and drive, condenser, evaporator, and the necessary control valves. With this type system, moisture, in the form of either liquid or fog, will not enter the cabin. Moisture present in the air passing through the Freon evaporator will condense on the cool surfaces of the evaporator. This condensation forms large drops which can be easily drained and dumped overboard.

During ground air conditioning operations, the vapor cycle system effects a rapid pull-down of cabin air temperature without the use of large external cooling carts. Ground operations are further improved by recirculating part or all of the cool cabin air through the Freon evaporator instead of dumping it overboard. Consequently, the load on the system and the time required to lower the cabin temperature are reduced.

The entire Freon loop system is packaged so that the unit can be removed for maintenance and servicing by removing three bolts and disconnecting three ducts.



Above: Cabin pressure regulator outflow valve.
Below: Cabin pressure regulator outflow control and indicator.

Cabin pressurization is automatically regulated by two cabin pressure regulator outflow relief valves, and a cabin pressure outflow control and indicator. One pressure regulator outflow relief valve is located in a pressurized area at the aft end of the airplane; the other is located in a plenum chamber containing electrical equipment, at the forward end of the airplane.

Each valve is a dual purpose outflow and safety valve to provide both cabin pressure relief and vacuum relief. In addition, each valve operates both mechanically and electrically.

Each outflow safety valve includes a filter, pneumatic relay, pressure relief mechanism, and an electro-mechanical actuator. The venturi serves as a vacuum sink for the pneumatic relay to provide power to operate the system at low cabin to ambient pressure.

The pressure balanced poppet-type outflow valve is operated either pneumatically by a diaphragm, or electrically by an electromechanical actuator, with switches located on the flight deck panel.

Each valve functions independently, offering an extra margin of protection. In the event of malfunction, the valves are designed to fail safely in the closed position so that one valve failure cannot result in cabin depressurization. Should one unit fail, the remaining outflow valve is capable of maintaining normal control of cabin pressure.

The forward outflow valve, located in the electrical compartment below the cabin floor, exhausts cabin air overboard after it has been utilized for cooling the electrical equipment.

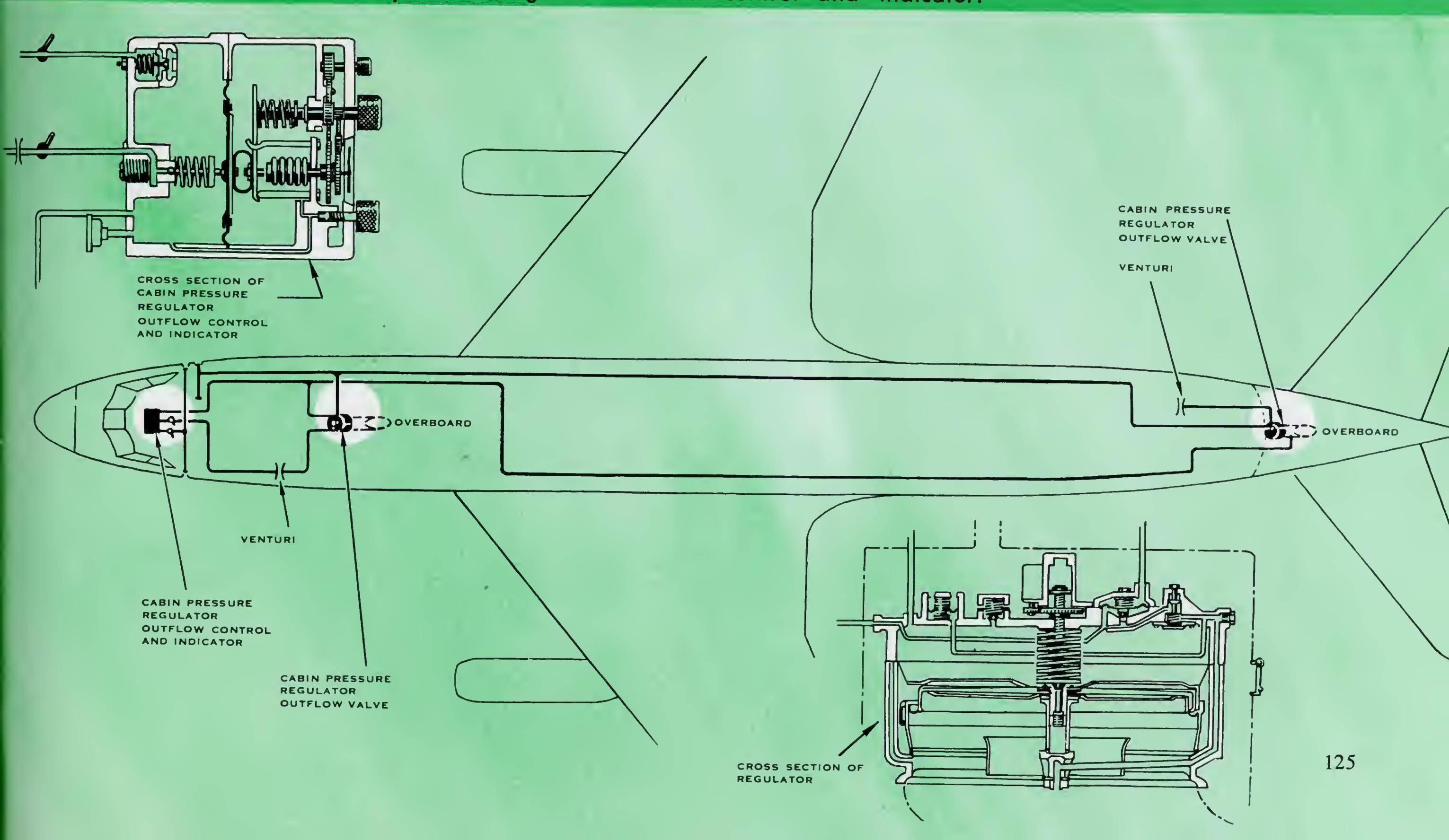
Either of the pressure regulator outflow relief valves is capable of maintaining normal cabin pressure schedules as selected by the flight engineer.

Under normal operations, 50±10 per cent of the total airflow passes through the outflow unit of each pressure regulator outflow relief valve. The outflow valve control incorporates a cabin altitude selector knob and indicating dial, permitting the selection of any cabin pressure altitude within the range of —1000 feet to +10,000 feet. During isobaric operation (constant cabin altitude), the variation in cabin pressure altitude will not exceed ±150 feet at a maximum rate-of-change of 50 fpm.

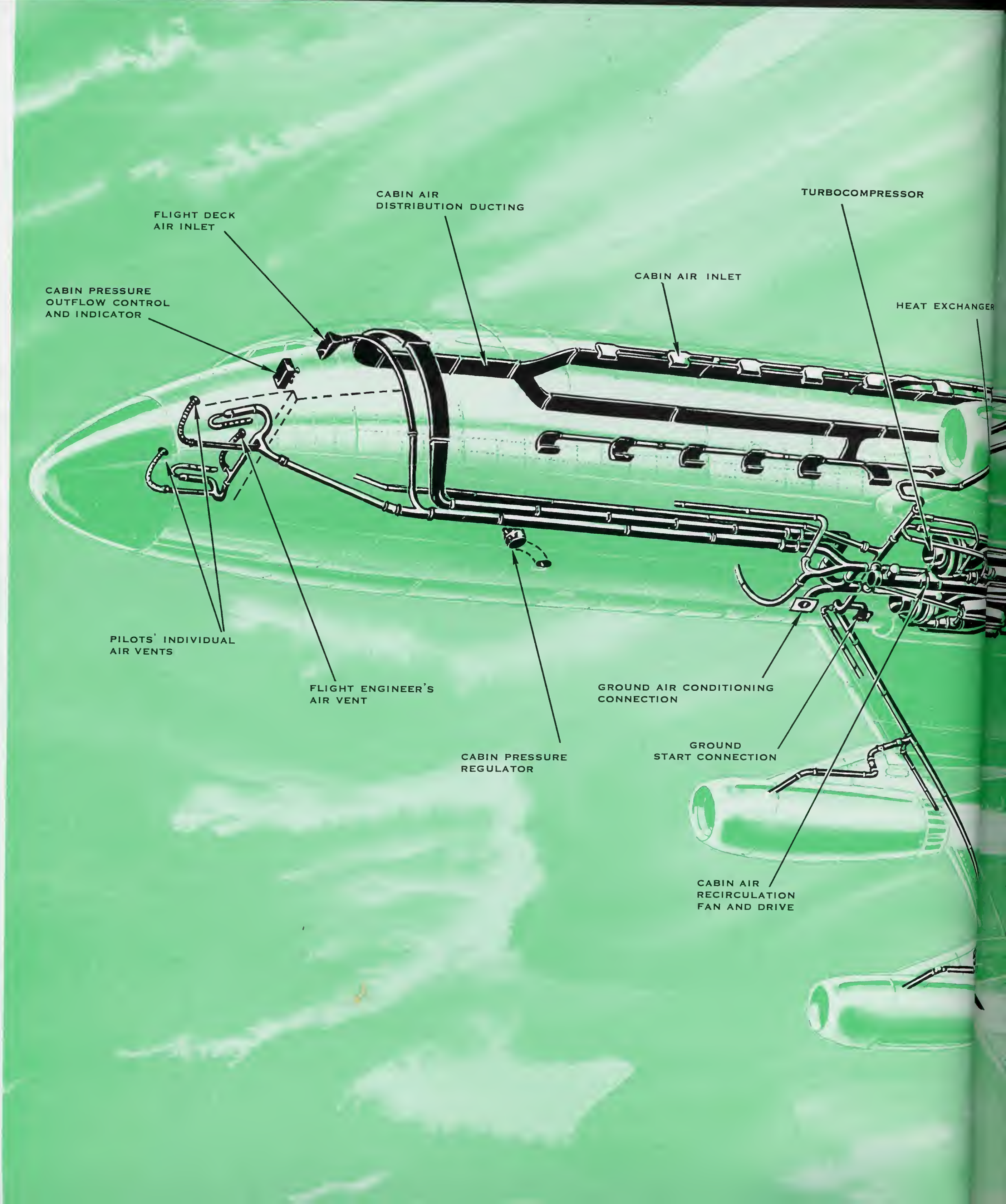
Controls and instrumentation on the flight deck panel permit preselection of cabin pressure change rates and cabin pressure altitudes. Cabin differential pressure and altitude gages give a visual indication of the pressurization system operation. A secondary means is provided for cabin pressure regulation by two toggle switches which individually control each regulator by means of an electric motor mounted on each outflow valve. The outflow valve control incorporates a barometric pressure adjustment to correct for airport barometric pressure variations at time of takeoff and landing. On landing, a landing gear switch energizes the electrical actuators on the outflow valves to fully open the valves and release cabin pressure. During takeoff, the procedure is reversed.

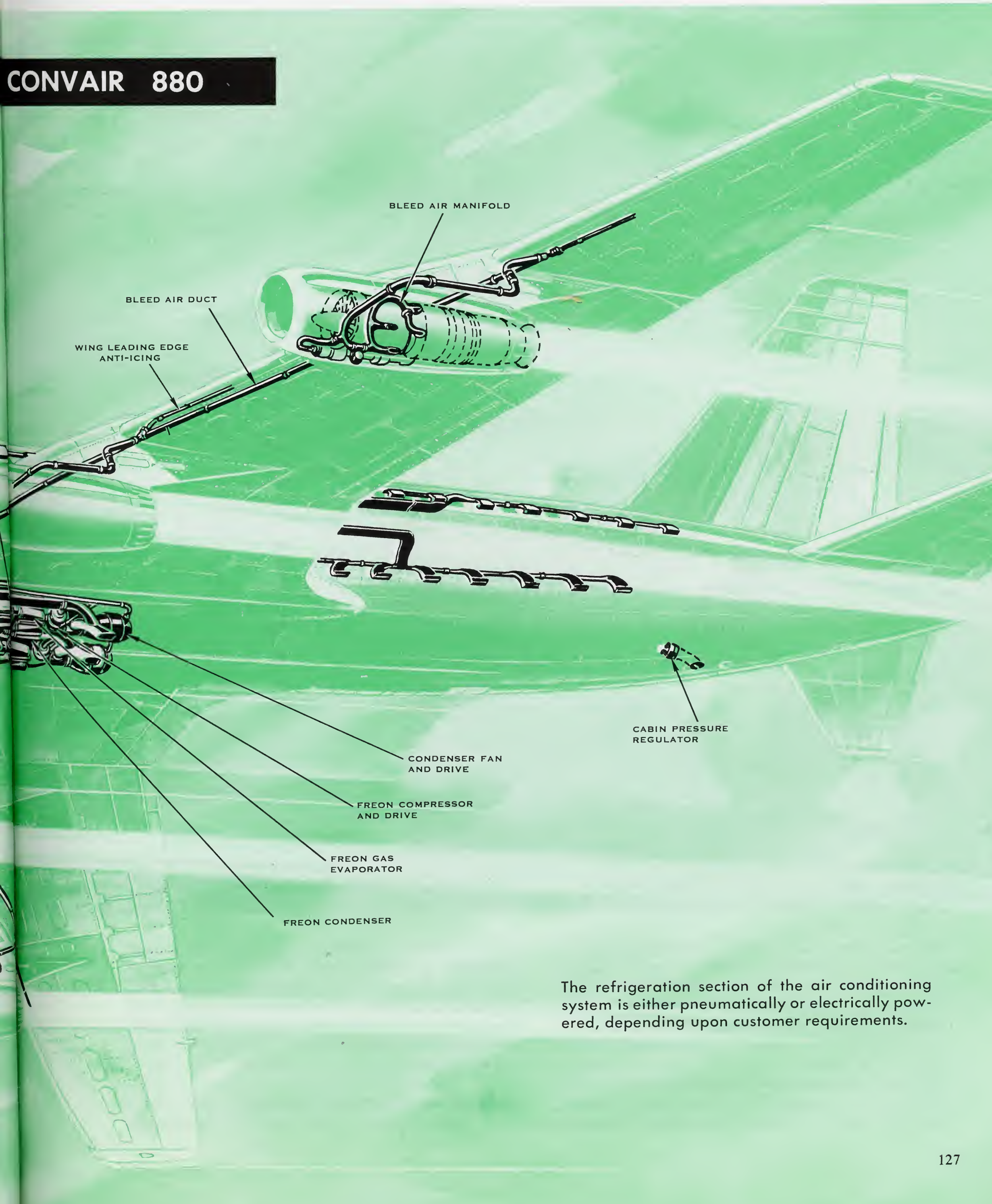
In flight, ram air enters the air conditioning compartment plenum chamber through two ram air intakes, located on the lower surface of the "880" fuselage, near the leading edge of the wing. Ram air is introduced into two turbocompressors which are driven by bleed air from the main bleed air duct manifold in the ram air plenum compartment. The compressed ram air from the turbocompressor is then routed through a flow-control sensor and into an

Schematic of cabin pressurization system and sectional views of cabin pressure regulator outflow valve and cabin pressure regulator outflow control and indicator.

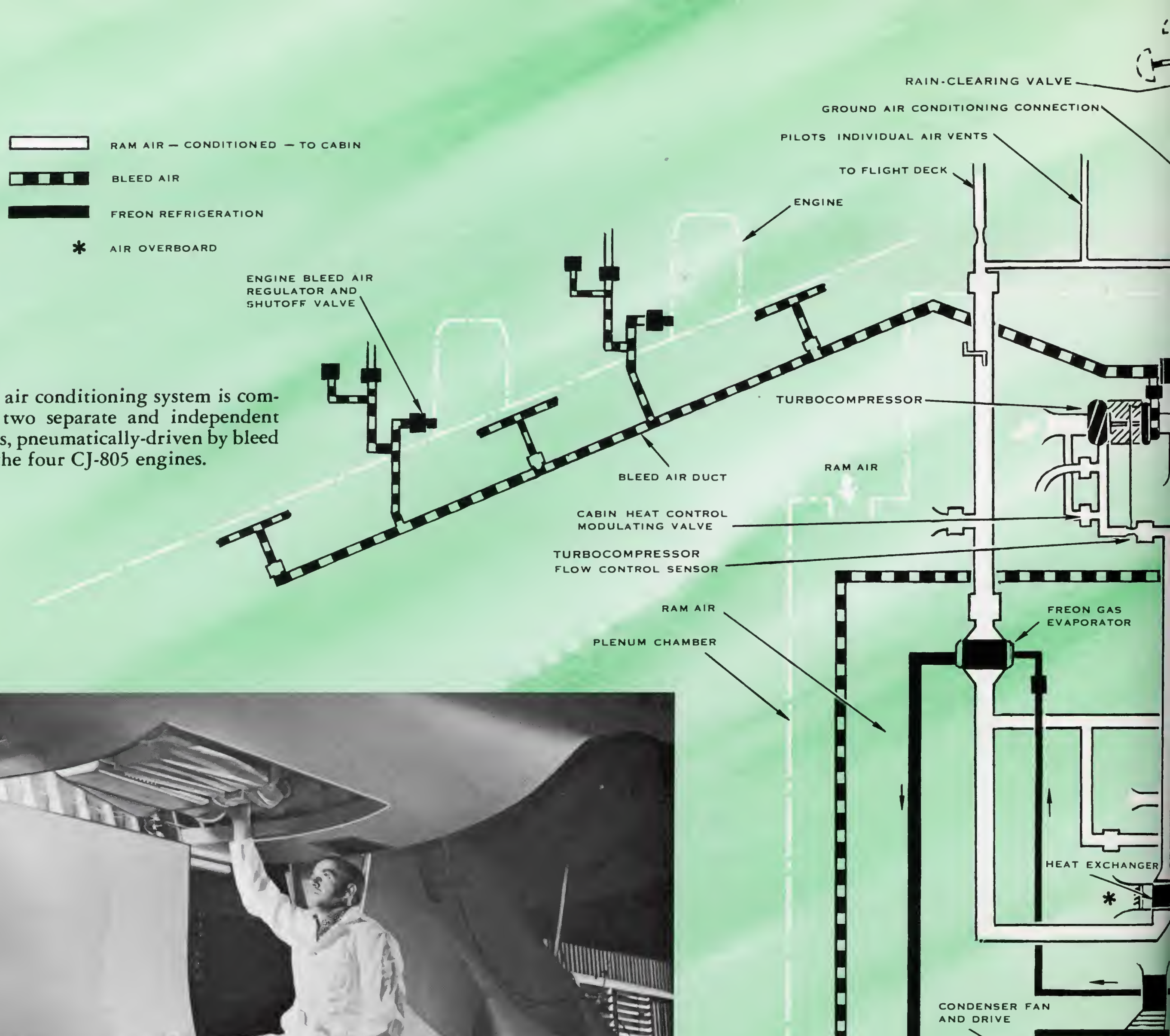


AIR CONDITIONING and PRESSURIZATION SYSTEM for the





The refrigeration section of the air conditioning system is either pneumatically or electrically powered, depending upon customer requirements.



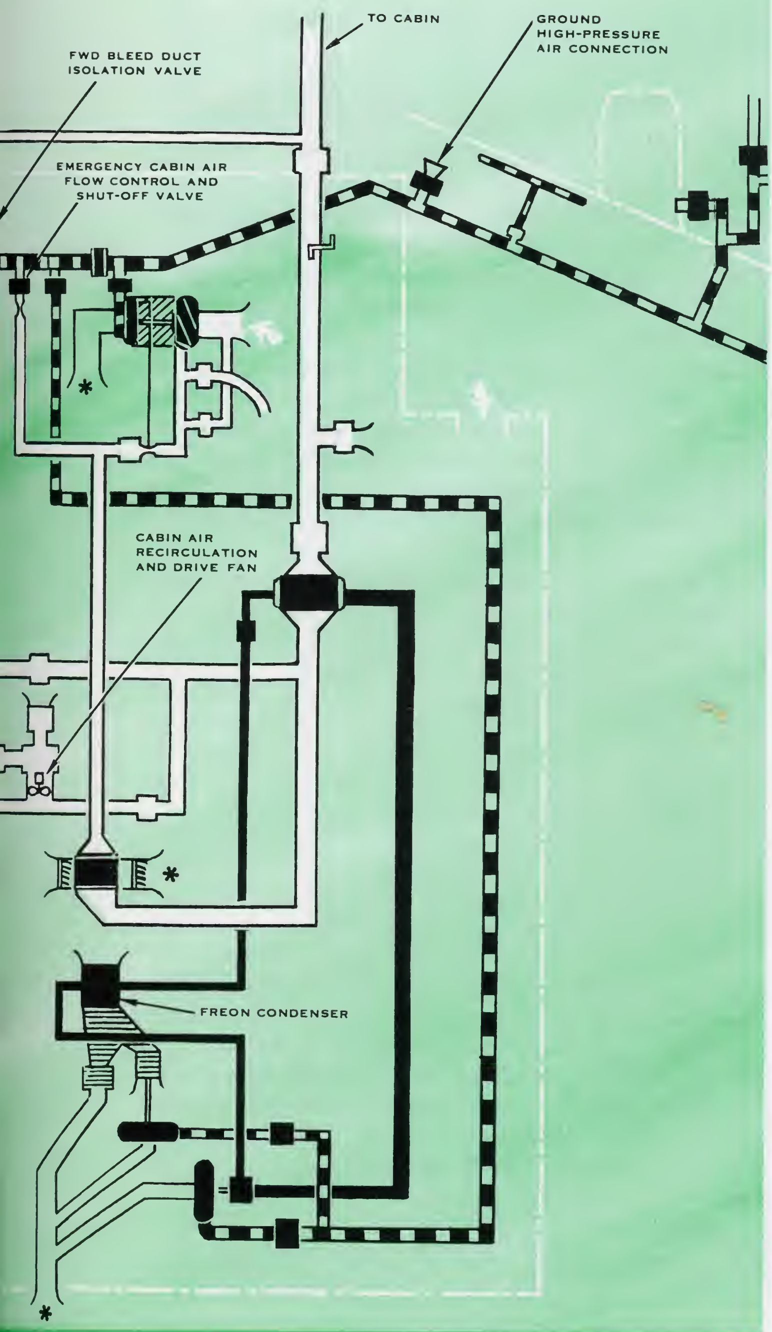
The basic air conditioning system is composed of two separate and independent subsystems, pneumatically-driven by bleed air from the four CJ-805 engines.

The entire Freon system is packaged so that it may be removed for servicing.

air-to-air heat exchanger, which reduces the temperature of the compressed air. This compressed air is then ducted through a Freon gas evaporator which further reduces the temperature of the air to the required demands of the cabin and flight deck.

A cabin heat control modulating valve controls the amount of turbocompressor discharge air recirculation. The temperature control system initiates a signal to the cabin heat control modulating valve, to the heat exchanger cooling air modulating valve, and to the Freon compressor drive modulating and shutoff valve. By a sequence of modulating, closing, and opening of these valves, any desired temperatures within required limits can be obtained for the cabin and/or flight deck.

Engine compressor bleed air provides an air source of 237 psig maximum pressure and 867°F maximum



Schematic of cabin pressurization and air conditioning system.

temperature. The engine bleed air pressure regulator "tops off" bleed air pressure to a maximum of 40 psig and incorporates a check valve to allow engine starting. The regulator also provides a means for shutting off bleed air at the source.

Bleed air, manifolded from each engine bleed air port through a bleed air pressure regulator, is ducted into the bleed air manifold duct in the wing leading edge between the forward spar and a fiberglas anti-icing discharge air baffle. This space is purged with ram air in flight. The ram air flow serves to remove the heat dissipated from the bleed air lines and insures that the wing front spar structural temperature does not exceed 200°F.

After the compressed ram air from the turbocompressors is cooled through the Freon evaporators, it is carried in respective lines to the cabin and flight deck. A manifold duct connects the cabin and flight deck lines together, upstream of a flight deck flow limiter. This manifold duct allows the excess air flow, above the needs of the flight deck, to divert to the cabin line. The conditioned air to the flight deck is distributed to the pilot, copilot, and flight engineer through a system of individual adjustable outlets, resembling piccolo tubes, and a compartment inlet. The conditioned air to the cabin is distributed to the passengers through openings below the hatracks on each side of the cabin, above alternate cabin windows. Individually-adjusted outlets are provided in the hat rack panels and in the buffet and each lavatory.

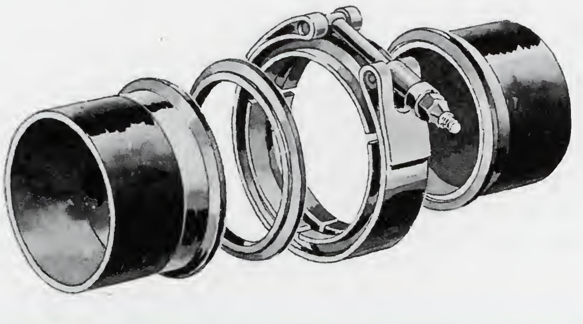
During steady-state operation, a thermostatic expansion valve allows Freon liquid to enter the evaporator at a rate which insures complete vaporization of the liquid before it leaves the evaporator. The vaporized Freon is then ducted to the compressor which increases the pressure and temperature of the gas. The compressed gas is directed to the condenser where the heat is removed by cool ram air flow. The cooling action condenses the Freon gas back to the liquid. The liquid Freon leaves the condenser, according to the demands of the thermostatic expansion valve, thus completing the cycle.

An alternate source of ram air is provided for an unpressurized flight condition in the event both turbocompressors or both Freon systems fail. During unpressurized flight at 250 knots IAS and 8000 feet altitude, the ram air flow to the cabin and flight deck will not be less than 140 pounds per minute. No heat is supplied during this operation.

An alternate bleed air system is provided for use in lieu of turbocompressors at altitudes above 10,000 feet. Bleed air for the system is taken from two places in the main bleed air duct, located in the ram air plenum compartment. One bleed air line connects into the flight deck turbocompressor outlet and the other line connects into the cabin turbocompressor outlet. A flow-control and shutoff valve is provided in each bleed air line. A check valve is provided in each supercharger outlet line upstream of the bleed air line connection into the supercharger outlet. This prevents the bleed air from flowing out of the superchargers if bleed air pressurization is required.

To accommodate wing bending and thermal expansion in the wing leading edge bleed air manifold line, a compression bellows system is used.

Marman type LJ-11 duct joint couplings are utilized throughout the bleed air system. A special safety strap is also provided over the coupling "T" bolt. The safety strap prevents the coupling from disconnecting in the event of a failed "T" bolt.



Quick-Disconnect duct joint couplings are used throughout the bleed air system.

The complete bleed air system is covered with a ½-inch thick fluid-tight insulation, fabricated from fiberglas batting, and two layers of resin-impregnated fiberglas cloth. The bleed air duct joints also have a resin impregnated cover. The covers are split to allow installation and ready inspection of the bleed air joints. The ends of the covers are clamped to the duct insulation, providing a fluid-tight seal.

The following indicators and controls for the cabin and flight deck turbocompressors are located on the flight engineer's panel: overspeed trip warning light, rpm indicator, bearing temperature indicator, airflow indicator, and ON-OFF control switch. Location of ON-OFF control switch varies with different models.

Also on the flight engineer's panel are indicators and controls for the cabin and flight deck Freon systems: failure warning light, ON-OFF master control switch, and FLIGHT DECK OFF-BOTH ON-CABIN OFF control switches.

The following controls and indicators are utilized for cabin pressurization on the flight engineer's control panel: barometric pressure correction control knob, cabin pressure rate-of-change control knob, cabin altitude selector knob, cabin high-altitude warning light, cabin rate-of-climb indicator, cabin altimeter, cabin differential pressure indicator, a four-position AUTO-OFF-CLOSE-OPEN switch for each pressure regulator (the CLOSE and OPEN positions are momentary positions only), and FWD CLOSE and AFT CLOSE position indicator lights for each respective cabin pressure regulator outflow valve.

Both the cabin and flight deck have the following temperature controls: a three-position AUTO-OFF-MAN switch which provides for manual or automatic operation of the temperature control system, a two position MAN HOT — MAN COLD momentary switch for manual operation, and an INCREASE — DECREASE variable control for completely automatic operation of each temperature control system.

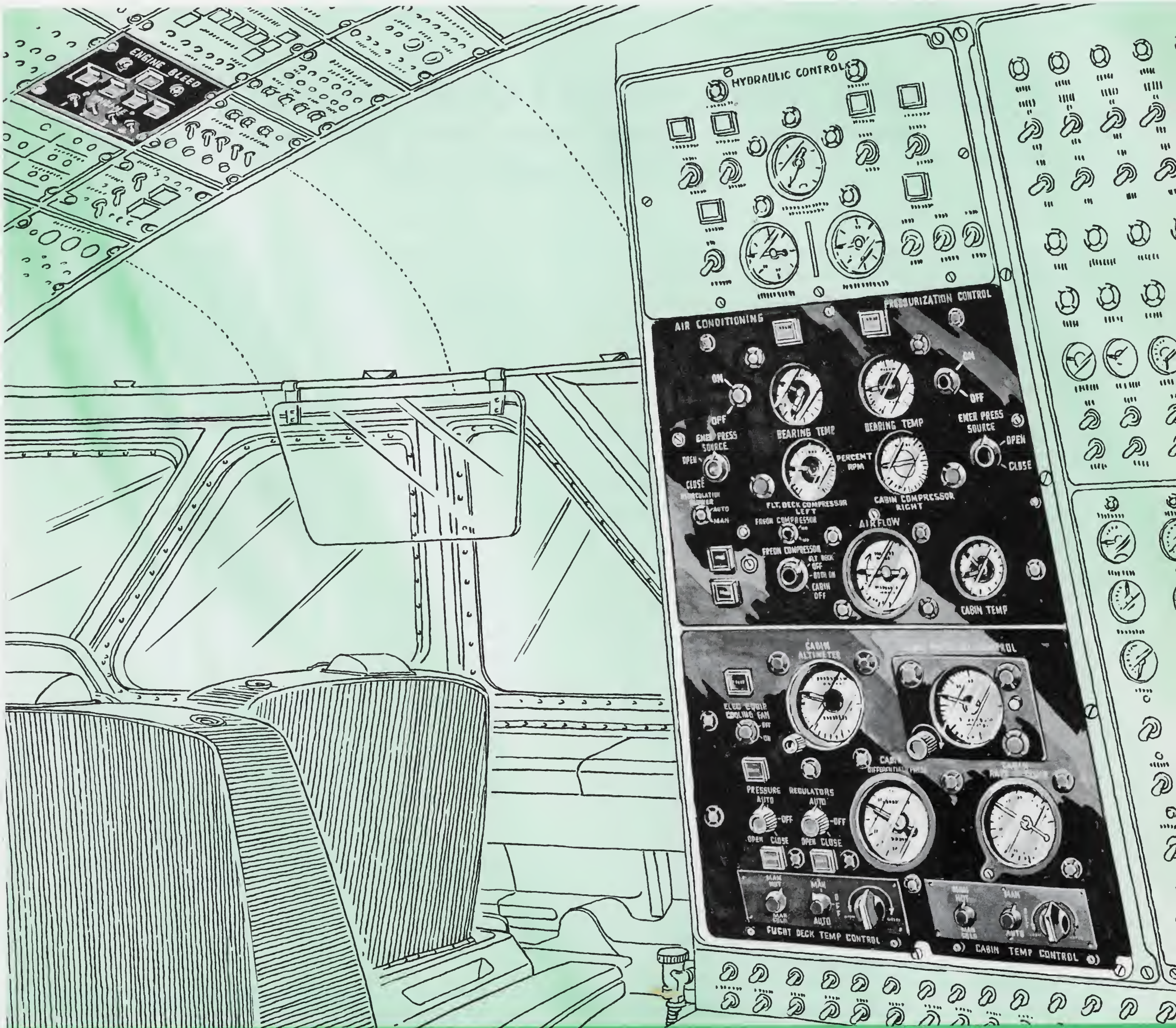
Switches are provided on the overhead panel in the flight deck for individual ON-OFF control of each engine bleed air pressure regulator. Adjacent to each switch is a malfunction light which indicates closure of the pressure regulator valve when it should be open and modulating.

Five additional switches are provided for the pneumatic-drive Freon system, and three additional switches are provided for the electric-drive Freon system. All of these switches are three-way units with AUTO-OFF-MAN-ON positions and adjacent excess-heat indicator lights. The switches are used for isolation control of applicable sections of the bleed air duct system in the event that a bleed air duct area becomes overheated.

For example: if a failure occurs in the left wing bleed air duct, a continuous wire overheat detector automatically closes the bleed air pressure regulator valves on the No. 1 and No. 2 engines, and closes the wing emergency isolation valve on the left side with switches in AUTO. At the same time, the excess-heat indicator light next to the respective wing isolation switch illuminates. These valves remain closed and the light remains on until the switch is moved to the OFF position. With the switch in OFF, the valves will remain closed with the light out. The valves may be reopened by turning the switch to MAN ON position.

If an overheat condition still exists, the excess-heat indicator light will go on again, but the valves will not close until the switch is manually returned to the OFF position. The temperature in the space adjacent to the bleed air ducts can be checked for abnormal conditions by a temperature indicator and rotary selector switch connected to individual space temperature pickups at several locations in each wing, and in the fuselage plenum chamber.

An extensive test program, consisting of a functional check of the complete "880" air conditioning system, has been underway for several months. Tests have been performed by simulating operation of the air conditioning system in the cabin, flight deck, and baggage compartments, to determine system compliance with Convair 880 design specifications.

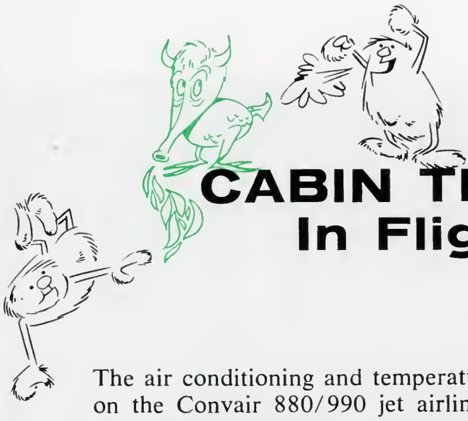


Engine bleed control panel and flight engineer's cabin pressurization and air conditioning control panel are conveniently located on flight deck.

Tests to insure a balanced air flow were conducted in the full-scale mockup of the complete airplane. Air distribution ducts were installed and calibrated to give optimum performance under all anticipated conditions of normal operation, using various instruments to determine air velocities, noise levels, and temperature gradients.

Air conditioning tests were also performed in a full-scale cabin constant section of the Convair 880. The section was 19 feet long and completely equipped with upholstery, carpeting, seats, hat racks, and insulating materials. The entire section was sealed and placed in an environmental test chamber to simulate actual temperature conditions as they would occur at an airport on a very hot day or at altitudes up to 41,000 feet. Temperatures in the test chamber were varied from —65°F to +160°F.

Structural endurance tests were run to determine bleed air duct reliability. Stainless steel duct specimens from the wing leading edge were subjected to a pressure-cycling test at 800°F, and a 20,000-cycle bending test. The bending of the duct simulated the maximum wing flexure encountered during flight conditions. Further testing involved high-mach air flow through the duct at various temperatures up to 700°F.



CABIN TEMPERATURE CONTROL
In Flight and on the Ground
Convair 880/990

The air conditioning and temperature control system on the Convair 880/990 jet airliners is designed to offer maximum comfort to passengers and flight crew during flight and while the airplane is on the ground. The system also protects susceptible aircraft equipment from temperature extremes that might interfere with their operation.

Through the coordinated operation of the various components that make up the air conditioning system, the following six basic functions are achieved: cabin pressure, air heating, air cooling, removal of excess moisture from cabin air, control of cabin air temperature, and ventilation.

At an altitude of 35,000 feet, the flight and passenger compartments are supplied with an airflow of approximately 110 pounds per minute. The passenger compartment receives a complete change of air every two and one-half minutes; the flight compartment, every minute. The cabin pressurization system is capable of maintaining the cabin altitude at sea level up to an airplane altitude of 21,300 feet, and the cabin altitude at 8,000 feet up to an airplane altitude of 41,000 feet.

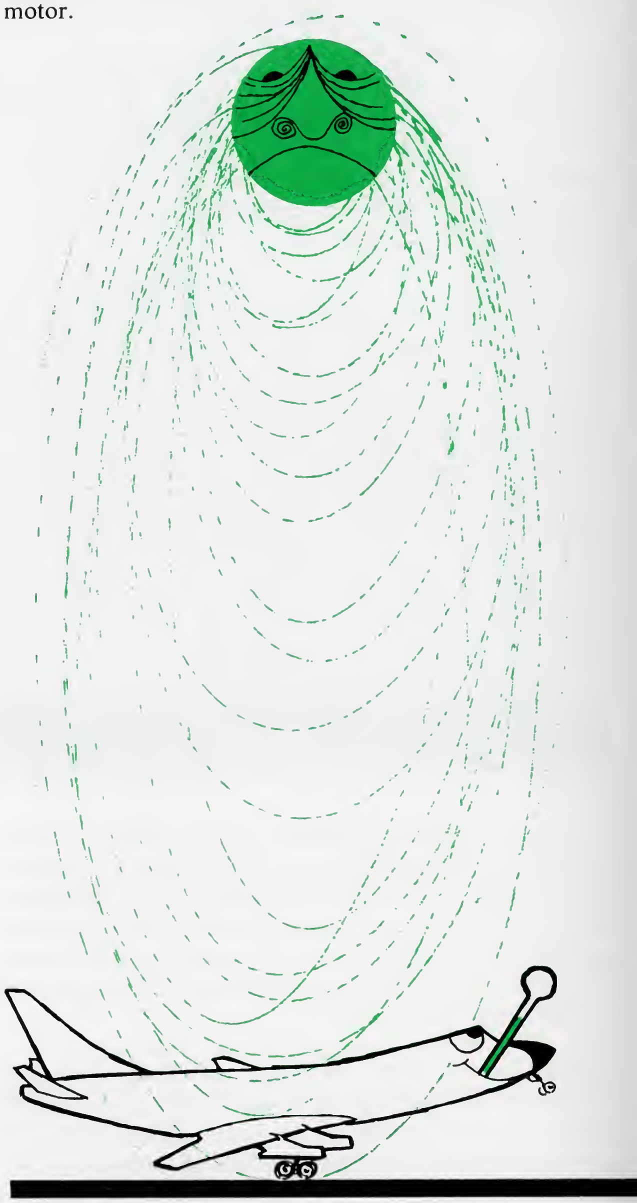
Despite the wide range of outside temperatures encountered during the course of high-altitude flight, the air conditioning and temperature control system will maintain cabin temperature at a comfortable 75°F (23.9°C). During ground operation, temperature on a 100°F (37.8°C) day will not exceed 80°F (26.7°C). The baggage compartment temperature is maintained above freezing at flight ambients down to −80°F (−62.2°C).

The flight deck and cabin temperature control systems on the Convair 880/990 are, for the most part, identical. Although interconnected by the necessary valving, they are normally independent of each other. To simplify the text, reference will be made only to the passenger cabin and, because customer requirements and installations of different models vary somewhat, a typical system will be discussed.

Normal in-flight and ground operation control of the air conditioning unit is accomplished automatically by the temperature control system. When in AUTO mode, the system keeps the cabin temperature at the setting of the temperature selector, and limits the inlet duct temperature to a maximum of 130°F (54.4°C).

Manual operation of the system is possible through the use of two toggle switches on the control panel. These switches function only when the AUTO-MAN-OFF switch is in the MAN position. The amount of heating or cooling is dependent on how long the MAN HOT-MAN COLD switch is held in the hot or cold position.

The automatic temperature control is made up of a comparison network, a magnetic modulator, three amplifiers, and the power supply. The comparison network incorporates a bridge circuit for compartment temperature error, and another for duct temperature limit. The magnetic modulator utilizes ac voltage to convert a dc temperature error signal into an ac voltage which is amplified to drive the sequencing device motor.



The sequencing device (one each for the flight deck and cabin) is installed on the Freon Pack. It consists of a reversible motor, a gear train, a cam shaft, switches, and potentiometers. This device signals the components of the air conditioning system in the proper sequence to obtain heating or cooling, as required. The sequencing device is positioned automatically by the temperature control system to maintain a selected cabin or flight deck temperature. The temperature selector (potentiometer) is used for selecting the desired temperature for the cabin and flight deck in AUTO. Placing the temperature selector in the desired position to either increase or decrease the conditioned air temperature causes a comparison of signals between the thermal resistors and temperature selector. The error signal causes the temperature control to position the sequencing device and thus schedule the following components and systems.

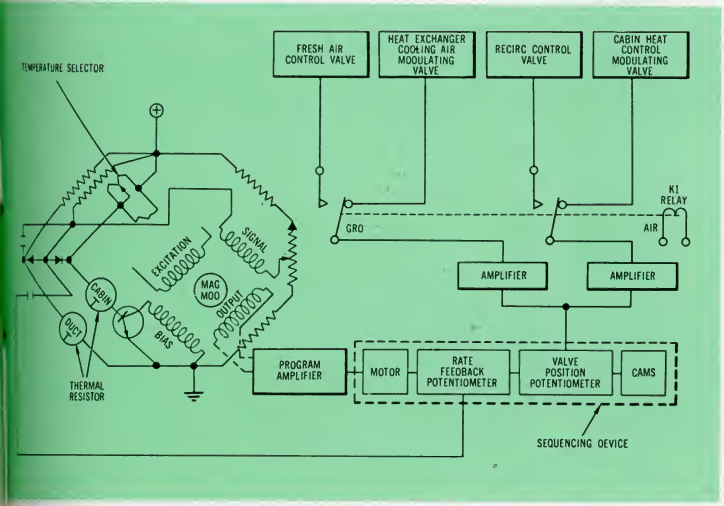
In-Flight Operation: Cabin heat control modulating valve; heat exchanger cool air modulating valve; Freon vapor cycle system control.

Ground Operation: Cabin air recirculation control valve and cabin fresh air control valve (on some airplanes); turbocompressors; Freon vapor cycle system control.

Electric heaters, cabin fresh air valve and cabin recirculation control valve, and components of the differential control system are scheduled by the sequencing device on those 880/990 aircraft so equipped.

Cabin and flight deck temperatures are sensed by thermal resistors located in the air exit ducts. They are electronically compared with the selected compartment temperature, and the difference between the selected and actual compartment temperatures actuates the sequencing device.

The Freon cooling system consists of closed vapor cycle refrigeration units containing fluid that absorbs heat during vaporization, and releases heat during condensation.



Typical temperature control schematic

A group of switches and indicators are available to control and monitor the Freon refrigeration subsystem. Controls consist of a Freon ON-OFF master switch, a cabin/flight deck control switch, recirculation fan switch, ram air source switch, malfunction lights for both Freon systems, and a cabin temperature indicator. A separate ON-OFF switch is available for the electronic compartment cooling fan and valve.

While the airplane is in flight, the turbocompressor system normally furnishes pressurized air to the cabin. Heating is gained by action of the cabin heat control modulating valve, which allows pressurized air to recirculate through the turbocompressor, and is regulated by the amount the valve is opened. Primary cooling is provided by the heat exchanger and is regulated by the heat exchanger cool air modulating valve. Secondary cooling is furnished by the Freon vapor cycle system.

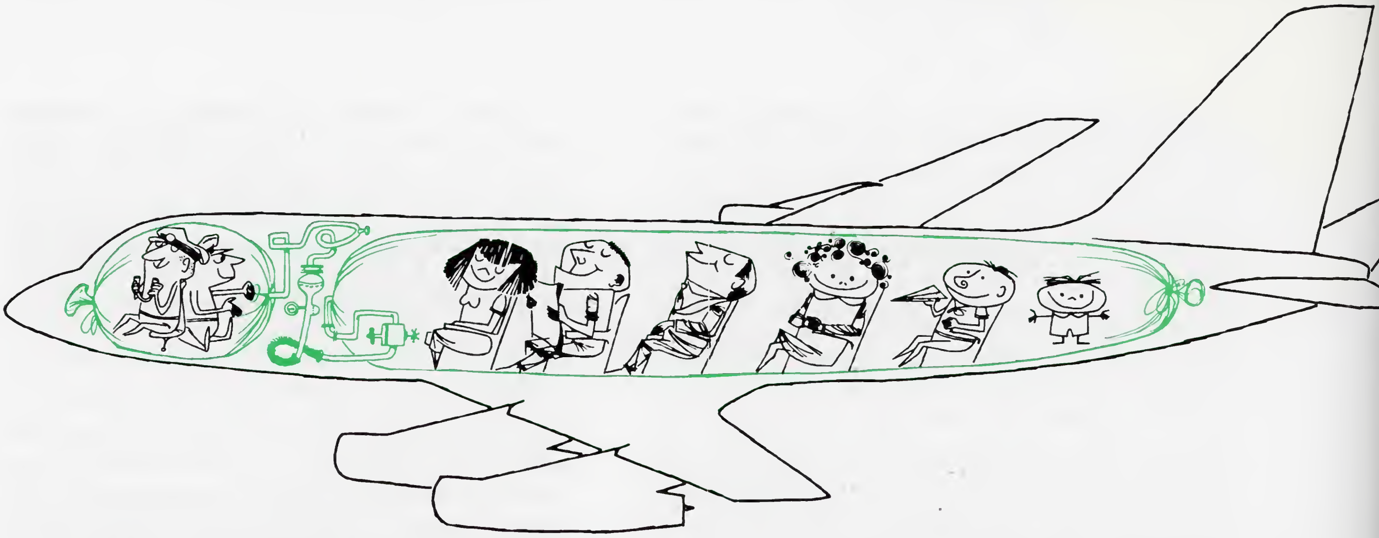
For maximum cabin cooling, in the electric-driven system, the cabin heat control modulating valve is closed, and the heat exchanger cool air modulating valve and the Freon back pressure regulating valve are fully opened. The turbocompressor system provides pressurized air which is ducted to the heat exchanger where it is cooled by ram air cooling from the open heat exchanger cool air modulating valve. From the heat exchanger, the pressurized air is ducted to the Freon evaporator and, because of the fully opened back pressure regulating valve, receives maximum Freon vapor cycle cooling. The cooled and dehumidified air then flows into the cabin, resulting in maximum cabin cooling.

To reduce cooling of the cabin air to the setting of the temperature selector, the back pressure regulating valve is slowly closed by the sequencing device. The cooling capacity of the Freon system is thus reduced and the Freon compressor shuts down when the back pressure valve closes. To further reduce cooling, the heat exchanger modulating valve is slowly closed by the action of the temperature control amplifiers.

The Convair 880M and 990 jet airliners have movable cabin partitions that can be relocated to divide the forward and aft sections of the cabin into different arrangements. Because of the difference in passenger loading that is possible in the two compartments, a differential temperature control system, in addition to the normal temperature control system, basically balances the heat gain between the compartments by supplying the necessary heat to the coldest compartment until both compartment discharge temperatures are within 2°F of each other.

The differential temperature control system consists of a temperature differential control box, a modulating power supply, a ground modulating power supply, two discharge air temperature sensors, two inlet air temperature sensors, and two forward and aft compartment heaters.

The amount of temperature differences between the two compartments is determined by the discharge sensors which send signals to the control box. The control box compares the signals and determines the coldest compartment and the amount of temperature difference. The modulating power supply, monitored by the control unit, automatically applies power to the two heaters in the coldest compartment at a rate deter-



mined by the temperature differential at the discharge sensors. This rate of heat application is compatible with the rate of temperature change that is determined by the inlet sensors which also supply signals to the control unit.

On the ground, the turbocompressor system is used for heating control on those 880/990 aircraft not equipped with the pneumatic-driven Freon system. On models equipped with the cabin heaters, the turbocompressor system is normally not used during ground operations.

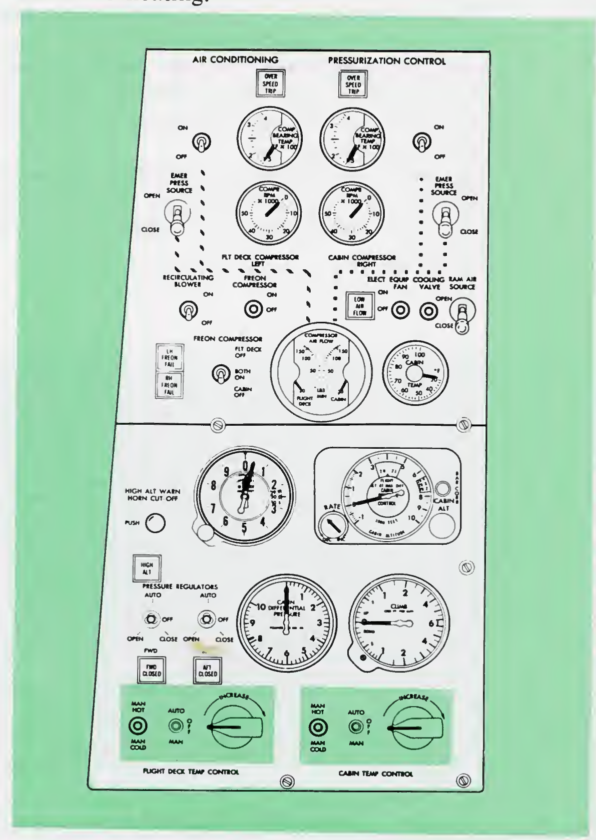
On heater-equipped models, the cabin air recirculating fan supplies air to the cabin. Ground cooling the cabin air is accomplished by the Freon vapor cycle system; ground heating the cabin air is performed by the cabin electric heaters. Various cooling and heating conditions are made possible by regulating the cooling capacity of the Freon vapor cycle system via the back pressure regulating valve, or regulating the cabin electric heaters.

When maximum cabin cooling is scheduled on the ground, the cabin electric heaters are off, the fresh air control valve (on some models) is closed, the back pressure regulating valve and the recirculation control valve are fully opened. Cabin air is drawn through the open air valve by the recirculation fan and is ducted to the Freon evaporator for maximum cooling. Leaving the evaporator, the cooled air is ducted into the cabin through the inoperative electric duct heaters.

On those aircraft with the fresh air valve, the sequencing device gradually closes the recirculation control valve and slowly opens the fresh air control valve, in the event the cabin air requires less cooling, thereby, increasing the temperature of the air entering the cabin. To reduce cooling of the cabin air even further, while the airplane is on the ground, the temperature control system operates in the same manner as when the airplane is in flight. The back pressure regulating valve is gradually closed, the cooling of the Freon system is reduced, and the Freon compressor shuts down when the back pressure valve closes.

Should heated cabin air be required after the Freon system shuts down, the cabin air heaters are turned on by the sequencing device. The electric heater elements are energized in a series of stages depending on the requirements necessary to supply the heating demand. The cabin sequencing device sends a signal to the ground modulating power supply, operating the forward compartment heaters in varying degrees. The aft compartment heaters are consequently slaved to the forward compartment discharge temperature and will maintain both the forward compartment discharge temperature and the aft compartment discharge temperature within 2°F of each other.

If additional cabin air heating is required after the cabin air electric heaters are fully energized, the sequencing device will slowly close the fresh air control valve (if installed) as it opens the cabin air recirculation control valve. With the fresh air control valve fully closed, the cabin air recirculation control valve opened, and all electric heater elements energized, the temperature control system will provide maximum cabin air heating.



Typical controls for regulating temperature of cabin and flight deck on Convair 880/990.

CONVAIR 880M/990

electrical power supply system

The basic electrical power supply in the Convair 880 and 990 jet airliners is 3-phase, 400-cycle, 115/200-volt alternating current, supplied by four 40-kva generators, one on each engine. All major components of the a-c system — constant-speed drives, generators, and generator and line controls — are supplied by one manufacturer, General Electric Company. The 28-volt direct current required is supplied by four General Electric 50-ampere transformer-rectifier units or, in emergency, by a battery.

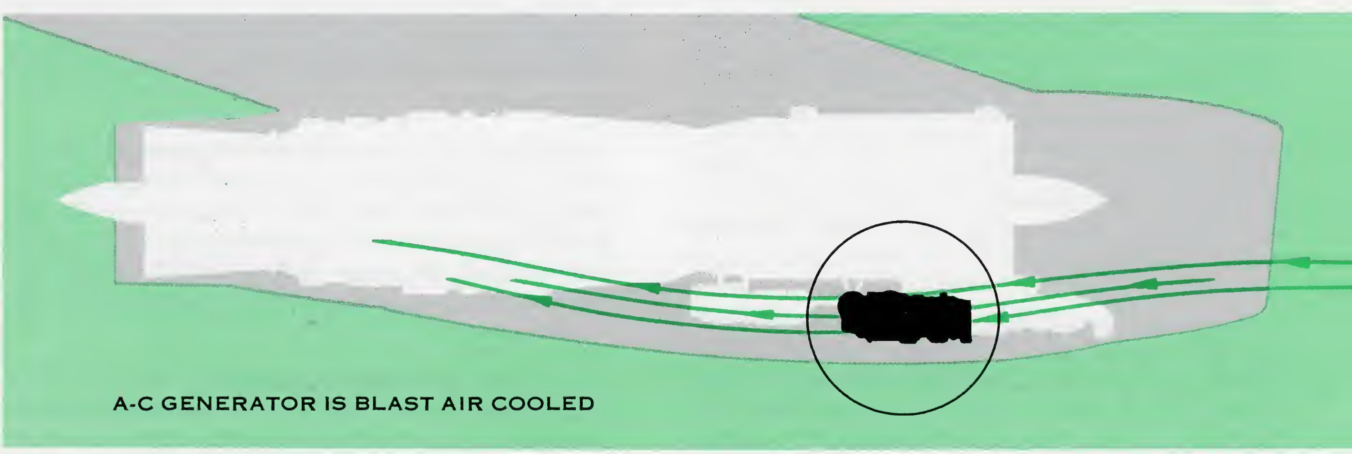
Before describing components and operation of the "880" and "990" power systems, it may be useful to review some of the design philosophy underlying the adoption of a basic alternating-current system. Prior to 1950, nearly all large aircraft used d-c generators, and supplied the required alternating current by adding inverters in the system. In the Convair 440, for example, alternating current was used only for instruments, radio, windshield anti-icing and autopilot operation. In the "880" and "990" d-c power is used only for certain instrument and radio applications, warning lights, solenoids, and electrical controls. All major power circuits are alternating current.

The present trend toward a-c electrical systems for aircraft has a historical parallel in the development of electrical power for industrial and commercial use. Though alternating current began to replace direct current in power systems a half-century ago, it is only in the last ten years that the state of the art has permitted development of an airplane a-c system.

Many of the reasons for using alternating current in a city power plant are equally applicable to an airplane system. A-C generators can be made smaller and more efficient; voltage can be varied for any requirement; and higher voltages mean less current in conductors and hence allow smaller wire sizes.

Two special considerations make a-c systems particularly desirable for aircraft: 1) at high altitudes, arcing in an a-c system is not the problem that it is in d-c commutators and switches; and 2) transformer-rectifiers for converting a-c to d-c weigh much less than do inverters for converting d-c to a-c.

Since load requirements have increased rapidly as airplanes have increased in size and performance capability, development of an a-c system became



A-C GENERATOR IS BLAST AIR COOLED

almost mandatory with the advent of jet-powered transports. Space and weight required for d-c generators, of a size to provide enough power for a 100-passenger 600-mile-an-hour transport, are prohibitive.

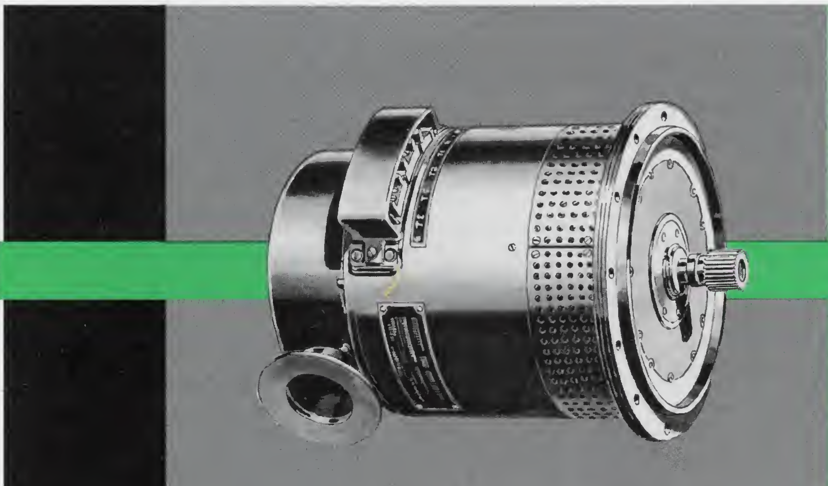
For aircraft use, the generator must be both lightweight and rugged. The generator in the "880" and "990" weighs only 76 pounds, while a 40-kva industrial generator weighs half a ton. This is possible because the aircraft generator has higher speed, higher frequency, and is blast air-cooled.

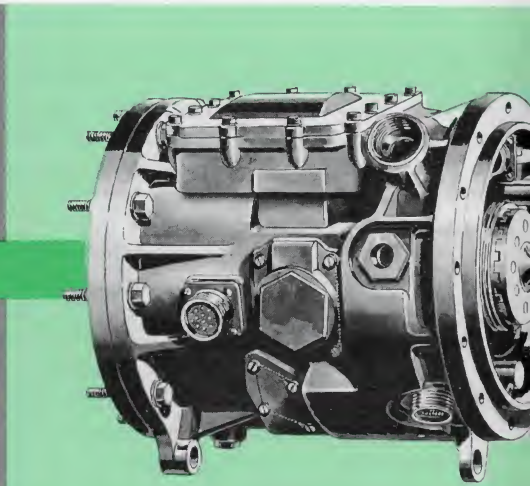
The breakthrough that has made possible a parallel a-c system came with the comparatively recent introduction of constant-speed drives. Constant voltage can be maintained in either a-c or d-c generators by electrical regulation; but parallel a-c systems must maintain a constant frequency as well, obtainable only by regulation of rotor speed. This regulation must be within fine tolerance for capacitance-inductance elements of the airplane as well as for parallel operation of the generators. A constant-speed drive was developed for holding rpm within limits to allow paralleling.

The constant-speed drives developed for the "880" and "990" will maintain the generator rotors at 6000 rpm within 1 percent tolerance, at all engine speeds from idle to maximum. This has made possible a sophisticated electrical system, automatic in normal operation, highly flexible in possible manipulation of load distribution when required, and with multiple safeguards against malfunction or system failure.

A-C power supply

The generator in each engine nacelle is driven by a constant-speed-drive (CSD) unit mounted on the aft face of the forward (transfer) gearbox. The gearbox is powered directly from the engine by a shaft geared to the compressor rotor.


GENERATOR


CONSTANT-SPEED DRIVE (CSD)

The CSD unit is a hydraulic, rather than mechanical, coupling. To describe it briefly and in the most general terms, the input and output drives consist of ball pistons moving in eccentric and elliptical races. One ball drive serves as a pump, the other as a hydraulic motor. Hydraulic flow varies, of course, with speed of the input shaft; it may also be varied by varying the eccentricity of the input race, which can be displaced by a lever actuated by a flyweight type governor.

Gross control is provided by the governor; for fine control, additional input is received from a current-sensing electrical component, the load controller. At 4300 input shaft rpm, hydraulic flow will be sufficient to drive the output shaft at 6000 rpm, and the flow rate can be held constant at all input speeds up to 7760 rpm.

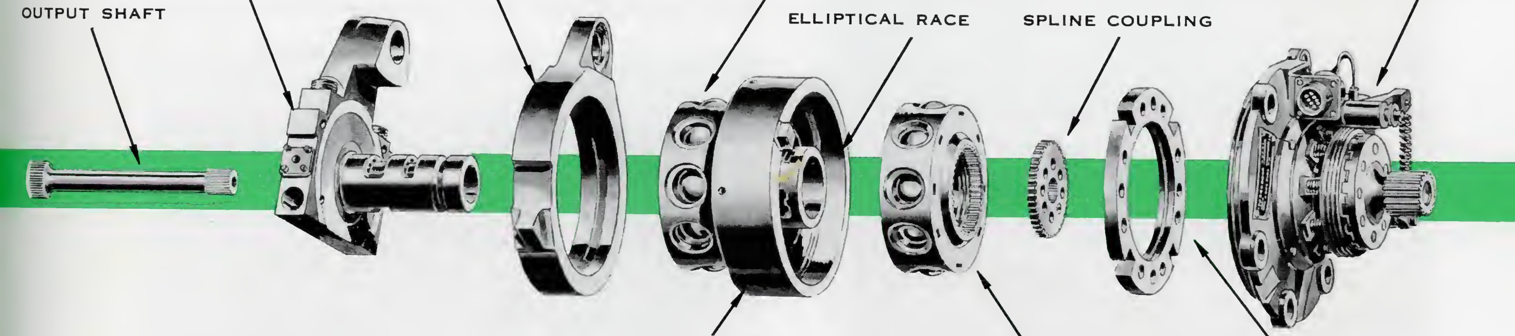
To prevent a runaway generator, in the event of a malfunction of the CSD unit, a solenoid-operated trip will completely disconnect the CSD from the drive pad by disengaging a clutch.

The generator is made up of fixed stator windings, from which power is taken, and a rotor containing a

series of electromagnetic field windings. On the same shaft is a permanent-magnet generator (PMG) field of 32 small magnets mounted around a disc. The PMG stator supplies approximately 300 watts of 1600-cycle single-phase current, which is rectified for use as a power supply for the control circuits, and also for "flashing" of the main generator field. After initial excitation, the rotor electromagnetic field is supplied by rectified a-c from the main output through the static exciter.

Slip rings are of monel for increased wear. Brushes and bearings are designed to last 2000 hours under "880" and "990" operating conditions. Expected life of the windings is 5000 hours.

The generator in the "880" and "990" designed for strength and durability in normal operation, will supply 150% of rated load for five minutes, and double load for five seconds, to withstand momentary overloading.



CSD EXPLODED VIEW

generator controls

The two principal controls for each generator are the static exciter and the voltage regulator.

The heart of the static exciter is a saturable-current potential transformer, a transformer with four windings (see schematic).

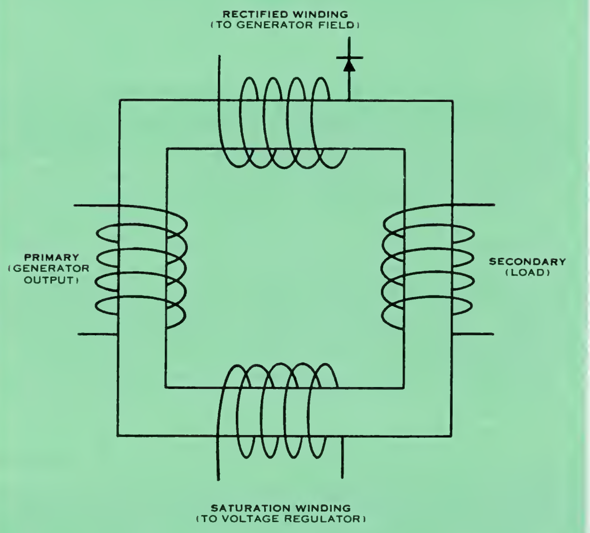
Initial flashing of the generator starts current flow in the primary winding, and transformer action causes current to flow in the rectified winding that supplies the generator field. This "feedback" current continues to increase, and voltage continues to rise until some limiting action is imposed.

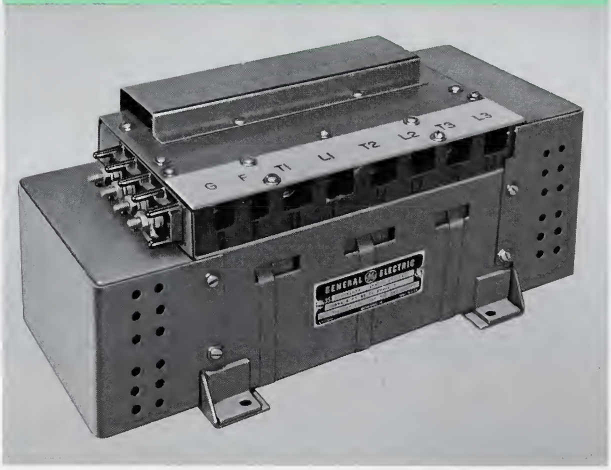
The saturating winding is fed with d-c power from the voltage regulator. As the unidirectional field of this winding builds up, inductive coupling between the other windings diminishes. The voltage regulator thus limits generator voltage by reducing both primary-secondary coupling and generator field current.

Also, a change in load further affects generator output; if more current should flow through the secondary because of a heavier load, the secondary will, with reference to the rectified winding, become a primary and induce more current in the generator field. With a fixed terminal voltage, the higher the load, the greater will be the feedback.

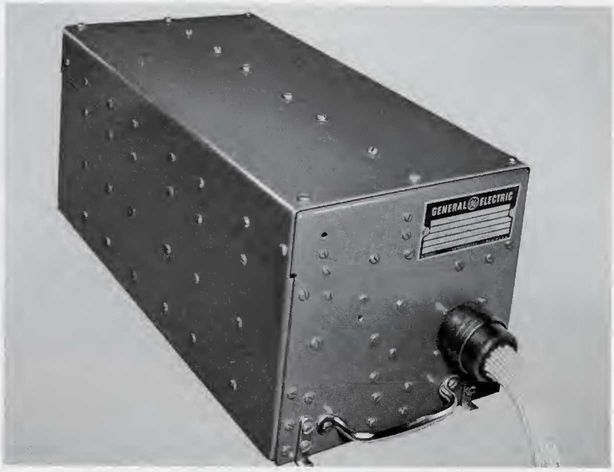
The static exciter is, to a certain extent, self-regulating and, under steady-state loads, the voltage regulator provides very little control. The regulator acts as a vernier, and provides additional forcing for rapid changes in system load.

The voltage regulator obtains power from the permanent magnet generator. A transformer- rectifier provides a supply of direct current at approximately 28 volts. The reference voltage, however, is provided by Zener diodes — silicon diodes that have the property of maintaining a constant voltage drop across the terminals, regardless of moderate changes in the voltage applied. A sensing circuit picks up phase volt-





STATIC EXCITER



VOLTAGE REGULATOR

ages, for comparison with the Zener diode reference, and the error signal directs output from a magnetic amplifier to the control winding of the static exciter, thereby regulating the current supply to the generator field.

The voltage regulator also receives an input signal proportional to the reactive current supplied by each generator in parallel operation. A reactive biasing circuit uses this input to further regulate the current supplied to the generator field to aid in evenly distributing reactive loads among the generators.

Some of the safeguards in the separate generator circuits may be mentioned here. A differential-protection circuit for each phase provides protection against between-phase faults or faults in the feeder lines from the generator terminals to the output load busses. Six transformer windings, one for each phase in the generator ground leg, and three at the line contactors, are connected in series loops and remain balanced during normal operation. If a leakage occurs in a feeder line, more current will flow in the ground leg, causing a potential across the transformer loops. If the potential exceeds permissible values, a differential protection relay will deenergize the generator.

An undervoltage magnetic amplifier type relay circuit provides protection against underexcitation or faults on the load bus. If the voltage in any phase drops below 96 volts, the relay drops out and, after a time delay of 4 to 8 seconds, the generator is deenergized. The time delay allows clearing, by thermal circuit breakers, of any fault on a distribution lead that might be causing the undervoltage.

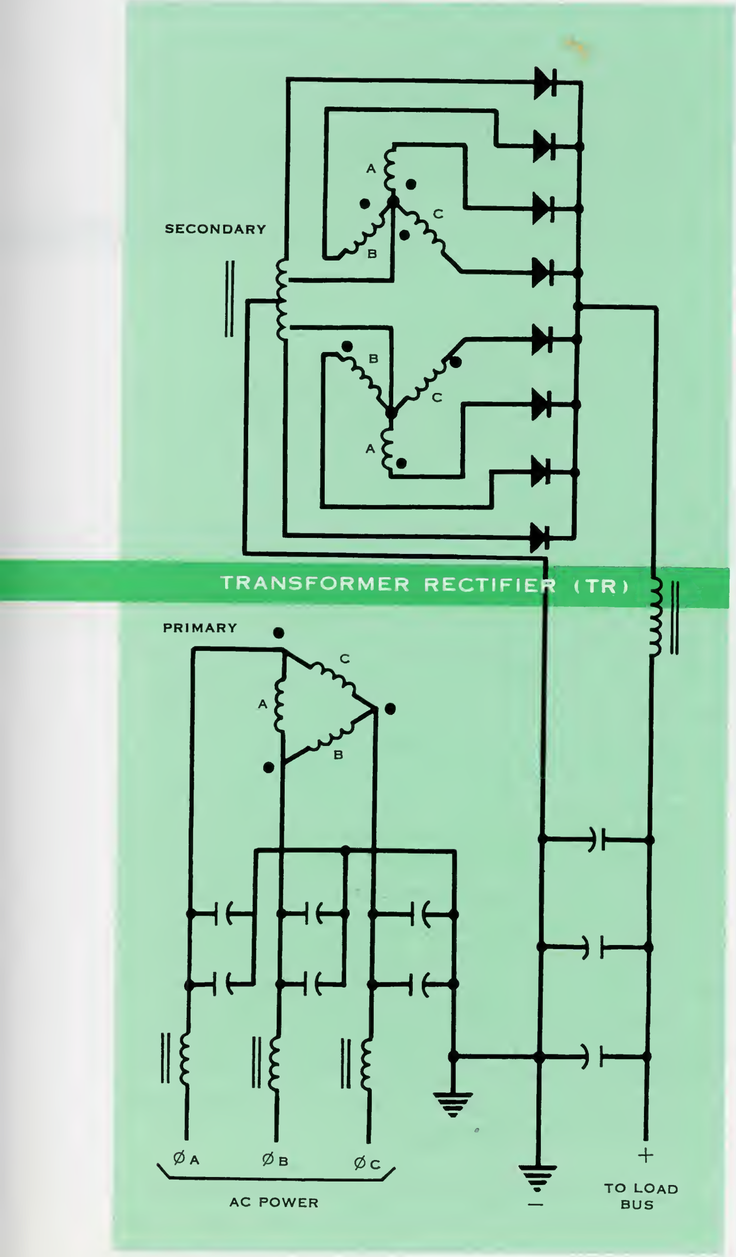
Another magnetic - amplifier type relay protects against overvoltage. This operates on an inverse time delay so that the time to trip the relay is inversely proportional to the amount of overvoltage. This gives maximum overvoltage protection while reducing the possibility of nuisance trips, due to switching transients.

All controls, except the static exciter, and all busses are accessible in flight, either in a compartment below the flight engineer's panel or through a door into the electronics compartment. The static exciters are mounted on the rear spar.

D-C power supply

The sources of d-c power in the "880" and "990" are four lightweight, compact transformer-rectifier (TR) units, and a battery for emergency use. Three of the TR units receive their power from Nos. 1, 2, and 3 generators, respectively; the fourth receives power from the pilot's essential bus.

The units are 28-volt, 50-ampere transformer-rectifiers, mounted in the electrical compartment. Input is at generator line (200-volt) potential. Windings are delta-double Y, with interphase transformer and eight silicon diodes. Peak ripple voltage is less than one volt. A radio noise filter is incorporated within the unit in the d-c circuit.



Normally, the TR units feed into busses — the essential and emergency d-c busses — which are connected by a normally-closed relay on the 880M. The "990" has a normally-open relay that may be closed by a switch on the flight engineer's panel. If the flight engineer's d-c control switch is turned from NORMAL to EMER, battery current causes the relay to disconnect the two busses so that the battery will supply only the emergency bus.

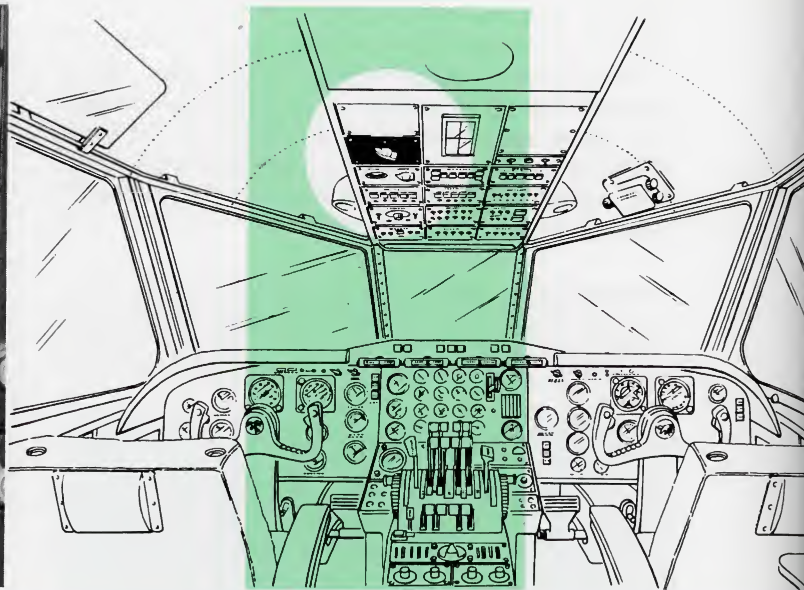
Under full 50-ampere-per-TR-unit load, the minimum of 24.5-volt potential required for the d-c system will be maintained. The battery is nominally 27.5-volt, and has a 13.5-ampere-hour capacity. It is kept in a floating charge condition during normal operation by a separate 20-ampere TR unit.

normal operation

For operation of the electrical system, it will be useful to examine the "880" flight engineer's control panel. The main generator switches are at the bottom of the panel with warning lights for "off" and "overheat" (of either bearings or windings). Above these is a watt-var meter and an ammeter for each generator. A single voltmeter and a frequency meter with a selector switch are at the left.

Following the flow lines upward, GEN LINE switches control the contactors that connect each generator to its load bus. BUS TIE switches control the contactors between the load bus and the synchronizing bus. The external power switch is on the left, with a flow line indicating that external power is delivered directly to the synchronous bus. This switch has three positions: OFF, ON, and GEN PARALLEL.

In a normal start, the engineer will close all generator, generator line, bus tie, and d-c TR switches, and turn the external power switch to ON. The synchronizing bus is then energized by external power and, from it, each of the load busses, via the bus tie contactors. However, the generator line contactors



PILOT'S ESSENTIAL BUS CONTROL PANEL 880M

will be held open by protective relay circuits. External power is now available throughout the airplane a-c and d-c electrical systems.

Since the generators are designed to have no residual magnetism during engine start, they will show no voltage. The generator field will not be energized until the engine comes up to idling speed. Then, the field is automatically flashed. The bus tie contactor automatically opens, removing external power from the load bus; the generator line contactor closes, so that the generator is connected to its load bus. When all four engines are started, the generators are carrying the full airplane load.

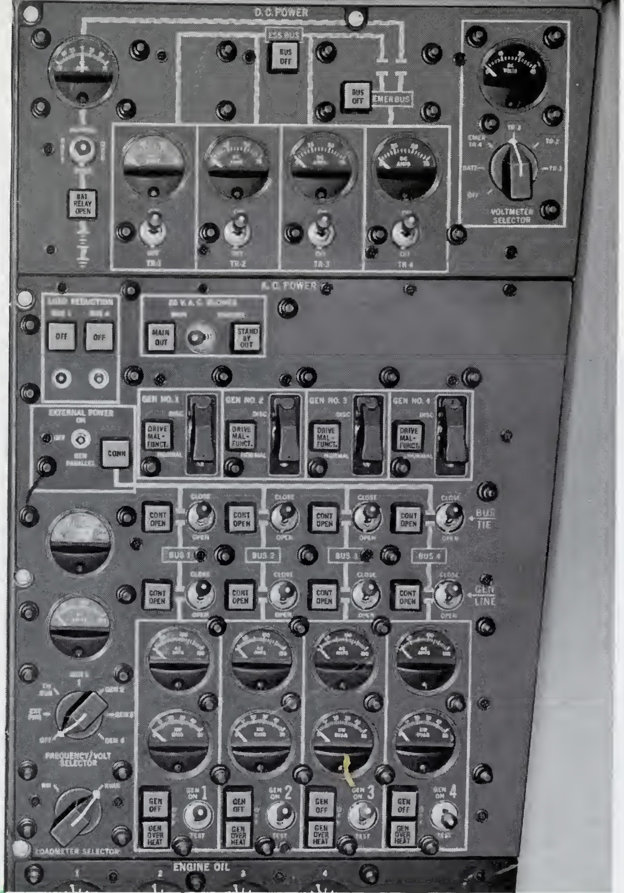
The flight engineer will turn the external power switch first to OFF and then to GEN PARALLEL. The No. 1 generator bus tie contactor will close, energizing the synchronizing bus from this generator; the Nos. 2, 3, and 4 generators will automatically parallel, and the bus tie contactors will close. The paralleling may also take place via the generator line contactors, if paralleling is necessary in subsequent manipulation.

An autoparalleling circuit prevents paralleling when frequency difference between incoming generator voltage and synchronizing bus voltage is more than 8 cps (400 cps ± 1%), and when phase difference is greater than 90°. Should random paralleling occur, however, no damage would ensue. The only effect would be a momentary transient in line voltage, with perhaps a perceptible flicker of lights.

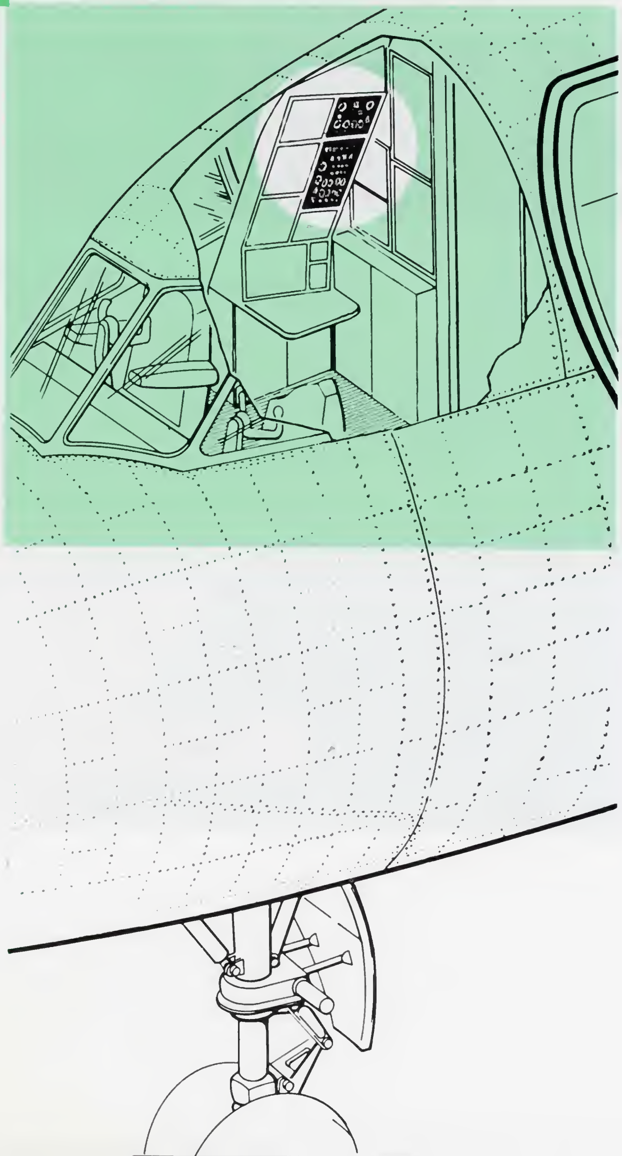
When the generators are in parallel operation, real and reactive loads are divided among them. The real load sensing components bias the CSD governors to increase or decrease generator torque so as to correspond with the others. Reactive load is similarly divided by biasing the voltage regulators to increase or decrease excitation. The loads are sensed by current transformers, connected into series loops on like phases of all generators in parallel.

In addition to the four load busses indicated on this panel, there is a fifth, the pilot's essential a-c bus. The control for this is a selector switch in the pilot's overhead panel. If the switch is in EXT PWR position, with or without external power connected, the pilot's essential bus receives its power from synchronizing bus. In other positions of the switch, the bus is energized by the generator selected. The lines to the individual generators bypass the bus tie and generator line contactors, so that multiple faults in the busses, feeders, distribution system, or contactors will not cut off power from this bus.

It may be noted that all this operation is automatic; after turning on the main switches, the flight engineer has manually operated only the external power



880M FLIGHT ENGINEER'S PANEL



switch, first to ON and then through OFF to GEN PARALLEL.

No. 2 and No. 3 generators supply essential busses; No. 1 and No. 4 supply non-essential busses. On the control panel, above the external power switch, are two load-reduction switches to remove load from the non-essential busses. To the right is a switch for main and standby 26-volt transformers.

Above the a-c panel is the d-c control panel. An ammeter is provided to show rate of charge and discharge of the battery. It also indicates state of charge of the battery, through interpretation of charging current. A voltmeter with a selector switch indicates battery or transformer-rectifier voltage, as selected.

Warning lights for generator line and bus tie contactors illuminate when the contactors are open; the external power light is on when the external power contactor is closed.

emergency operation

The design of the electrical power supply system is such that a number of malfunctions would have to occur before an airplane emergency would exist.

Some tracing of the electrical schematic will quickly illustrate this feature. These points should be noted:

1. Closing generator line and bus tie contactors will put any generator on the synchronizing bus, and the total synchronizing bus current will be available to the load busses.
2. Opening any generator line contactor removes the generator from both load and synchronizing busses, and leaves that generator's load bus energized by the synchronizing bus.
3. Opening any bus tie contactor takes that load bus off the synchronizing bus, leaving the generator supplying its own load bus.
4. Opening both generator line and bus tie contactors removes all power from that load bus.
5. Opening the load-reduction switches removes all power from the non-essential load busses, leaving the No. 1 and No. 4 generators free to supply the essential busses.
6. The pilot's essential bus can be supplied from any generator, whatever the status of the bus tie and generator line contactors, or from the synchronizing bus.

Summed up, any generator, or combination of generators, can be used to supply any load bus through the synchronizing bus; and any generator can supply the pilot's essential bus directly or through the synchronizing bus. The d-c system has the same flexibility, since the TR units derive their power from

three a-c load busses and from the pilot's essential bus.

Individual generator safeguards have been mentioned. The synchronizing bus also has protective circuitry against line-to-neutral, line-to-line, or 3-phase faults. Open phases, under- or overspeed generators, unbalanced loads between generators, or unstable operation of a drive or voltage regulator, will cause the faulty generator to be removed from the synchronizing bus, and its own protective circuits will remove it from the load bus. Some types of malfunction will remove all generators from the synchronizing bus; when the malfunctioning unit has been isolated, the others can be reparalleled.

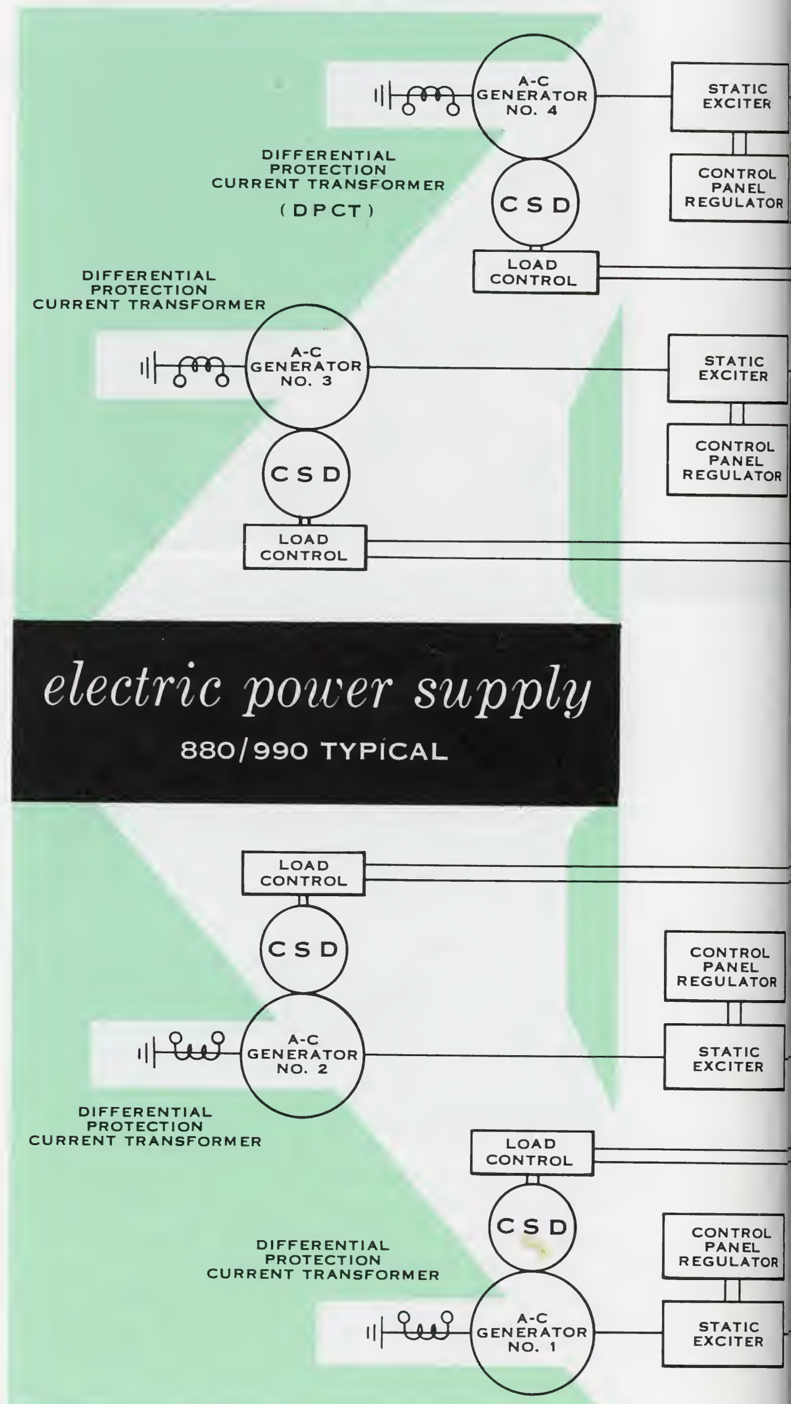
Since No. 1 and No. 4 bus loads are non-essential, and since either or both generators can be utilized for No. 2 and No. 3 essential busses, complete failure of any two generators would not constitute an airplane emergency. All normal controls and functions would remain. Power could be switched to non-essential busses for any desired special task.

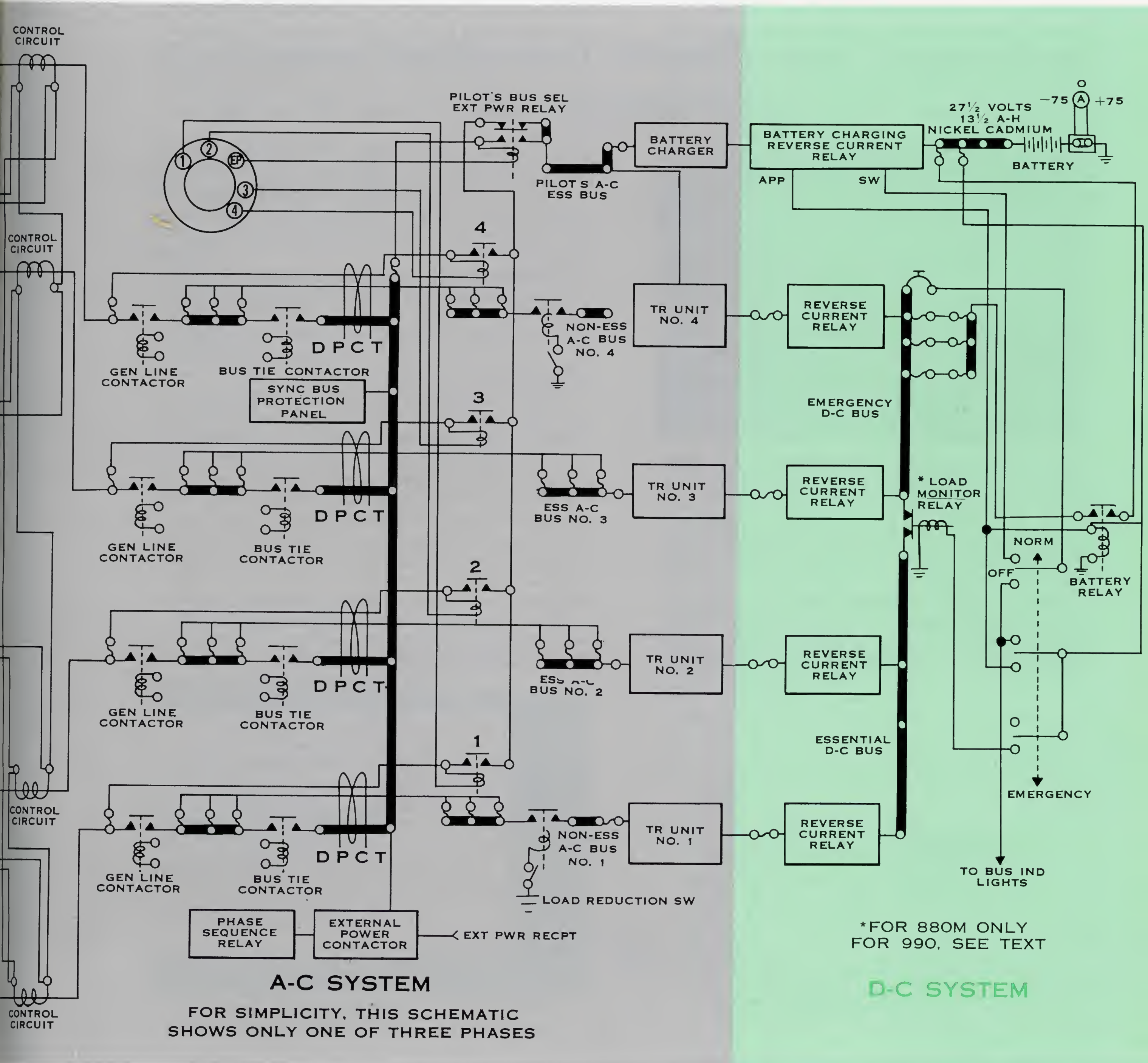
Should three generators go out, the pilot's essential bus would be switched to the remaining generator. This bus would use less than one-eighth of one generator's output, and 35 kva would still be available for essential functions. On the 880M, the battery switch would be turned to EMER, not primarily to provide current, but rather to reduce the load on the remaining TR units by disconnecting the d-c essential bus from the emergency bus. While one generator will not carry all normal loads on both essential busses, it will supply all emergency loads for safe and controlled flight and for landing.

Failure of all four generators — statistically inconceivable — would leave d-c power available from the battery. The d-c emergency bus would supply radio, essential engine controls, emergency warning systems, and fire extinguisher control, for a period of approximately one-half hour. Emergency flight controls require no electrical power.

Both tests and experience have proved that aircraft generators have a trouble-free service life extending into thousands of hours of operation. This integrity has been engineered into the generators of the "880" and "990" series airplanes. Integrity of components throughout the "880" and "990" electrical systems are consistent with that of the generators.

In addition, fail-safe design in the functional arrangement of the electrical systems precludes ultimate failure in all foreseeable areas affecting safety of flight. An eventuality which would dictate the possibility of complete reliance upon the capabilities of the 13.5-ampere-hour battery is inconsistent with the design reliability of the electrical systems.





A-C SYSTEM

FOR SIMPLICITY, THIS SCHEMATIC SHOWS ONLY ONE OF THREE PHASES

D-C SYSTEM

ELECTRICAL PROTECTORS
Convair 880/990

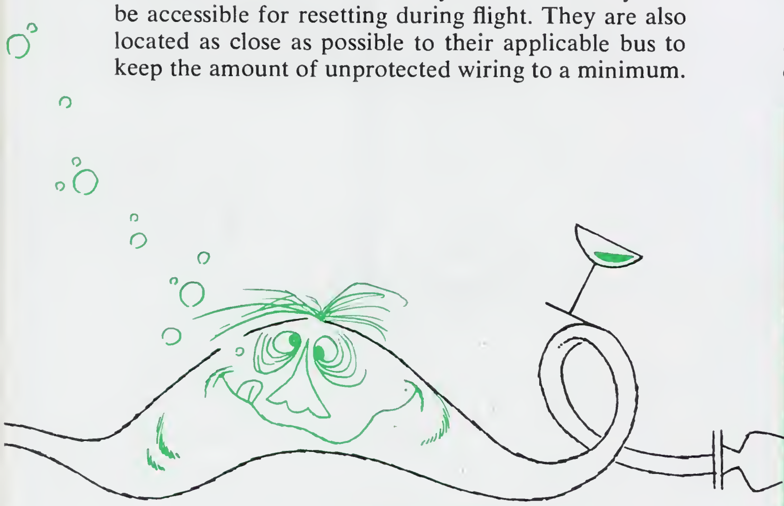
Circuit protectors on the Convair 880/990 jet airliners fall into two main types — circuit breakers (thermal type) and limiters. Circuit breakers and limiters are used to interrupt overloaded circuits under prescribed conditions. Circuit breakers differ from limiters in that they do not require replacement. A limiter causes an electric circuit to open under overcurrent conditions by the melting of its heat-sensitive element. It must be replaced after "blowing."

The receptacles for electrical protectors are clearly marked with appropriate amperage ratings. Each electrical protector is marked with its amperage rating and either a military specification (MS) number or the vendor's part number.

Circuit breakers and limiters are selected to give maximum protection by preventing electrical wiring from exceeding maximum operating temperatures. When necessary, the difference in ambient temperature between the circuit breaker and the wire location is taken into account.

The maximum current that a circuit breaker can safely interrupt is about 3500 amperes at 120 volts. They are designed to have an ultimate trip time at a temperature of 77°F, and will trip at 115 to 138 percent of rated current up to an altitude of 50,000 feet. Circuit breakers have the same ac and dc characteristics since their operation is caused by the heating effect of the load current.

Circuit breakers are usually located so they will be accessible for resetting during flight. They are also located as close as possible to their applicable bus to keep the amount of unprotected wiring to a minimum.



OVERLOADED CIRCUIT

Trip-free circuit breakers are used exclusively on the "880/990." The trip-free unit cannot be held closed by manual overriding of the trip mechanism while a tripping condition exists. This feature removes the possibility of burning out critical installations, such as emergency flight control systems.

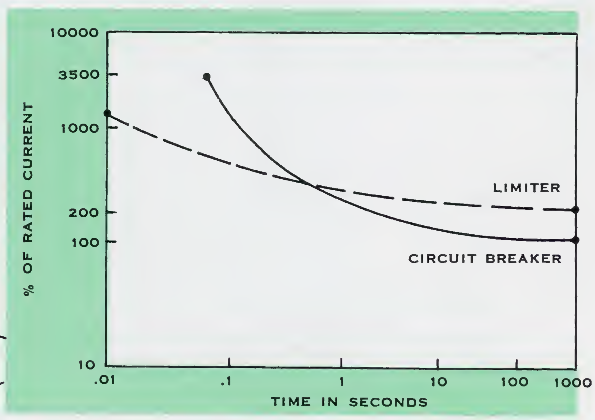
Limiters are usually applied to distribution systems on large utilization feeders to guard the system against extended overcurrents and short circuits. The function of the limiter is to provide the fastest, most positive isolation of a portion of an electric power distribution system in the event of high current overloads or short circuits, thus preventing prolonged or repetitive arcing or burning of wiring and equipment. Because of the high melting temperature of the fusible link that bridges the connections of a limiter, changes in ambient temperature encountered in the "880/990" do not have an appreciable effect on limiter performance.

As a general rule, high-capacity limiters do not require replacement during flight, because their usage is such that blowing would indicate the presence of faults that could not be repaired by the flight crew. Re-energizing the circuits could result in structural damage and/or fire.

The same general type of limiter is used throughout the Convair 880/990 airliner for both ac and dc power. Since limiters, like thermal circuit breakers, are heat-sensitive devices, they function irrespective of ac or dc. The rating of a limiter is determined by the wire gauge it protects.

Limiters are designed to carry approximately 200 percent rated current for at least five minutes, and to blow at 240 percent rated current in less than five minutes. Their interrupting capacities at 400 cycles are 4000 to 2500 amperes at 120 and 208 volts, respectively, and they are required to function in this capacity at altitudes up to 50,000 feet. A small button at one end of the unit pops out when the limiter link has melted, giving visual indication that a limiter has blown. A limiter will open faster than a circuit breaker under high current fault conditions.

The accompanying curve shows the basic trip characteristics of a circuit breaker versus the melting curve of a comparable limiter.



Shown above is graph comparing typical performance curves of limiters and circuit breakers.

Electronic Equipment Testing and Installation

Convair 880/990

Before a Convair 880 or 990 jet airliner is delivered to a customer, it undergoes a thorough equipment and systems checkout. Every item, from a simple switch to the most complex electronic system, must be in perfect working order before an airplane is released.

The task of handling all black boxes and instruments that go to make up the complex communication and navigation systems of the Convair 880/990 aircraft is accomplished by Convair's Electronics Installation Department.

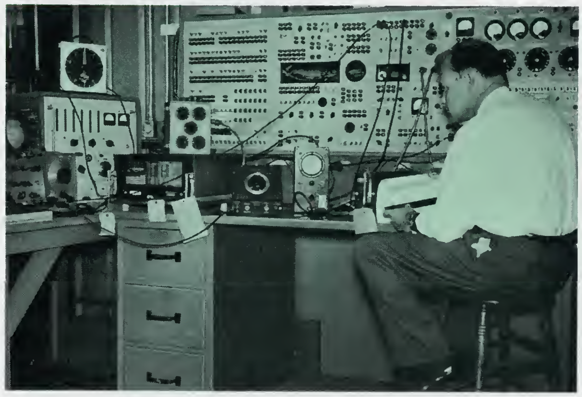
The number of systems handled will vary with individual airline requirements. They may include all or part of the Communications and Navigation Systems, DMET, ATC, Weather Radar, Terrain Warning, and Doppler.

Various test tools, which have no counterpart in commercially-available equipment, had to be built by Convair. As an example, two individual test tools were built to handle both Sperry and Bendix Autopilot and Compass systems... one for each vendor's equipment.

An interesting unit designed and built for use in conjunction with the Sperry Autopilot and Compass test tool is a small torquemeter for measuring minute rotational torque values, in either direction. The torquemeter indicates torque from 0 to 30 gram-centimeters with extreme accuracy.

Also used with the Autopilot and Compass test tools is a small precision synchro. The synchro itself is a standard off-the-shelf item, but, the mounting is of unusual design. With machined gears, unusual reading accuracy of one one-hundredth of a degree is obtained. When testing a compass card, plus or minus one degree is the maximum accuracy required. For testing the computer sections of the Autopilot and Compass systems, vendors' Customer Test Specifications call out accuracies within one tenth of one degree for a test synchro.

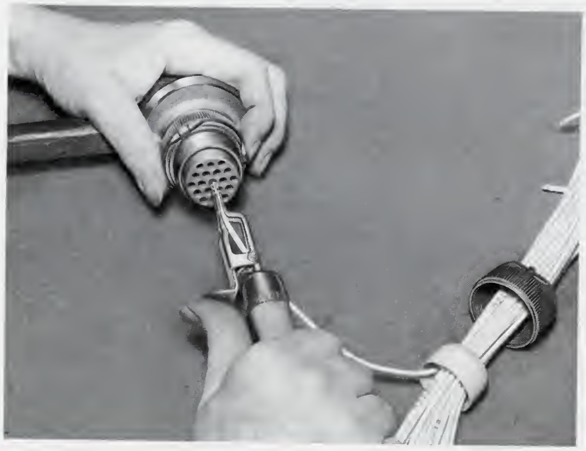
Any of the now available commercial weather radars may be tested on a Convair-built Weather Radar test stand by using separate dummy plugs to handle wiring changes. When a radar system is checked out on the test stand, all components are readily accessible for adjustment and calibration as required. The location of the testing area is such that mountains, extending from 19 to 37 miles at a known azimuth bearing, are used for calibration purposes. Either a vertical gyro or an accurate simulated gyro signal may be used for adjustment of the stabilization circuits along with physical displacement of the radar antenna in roll and/or pitch.



Engineer checks out Bendix autopilot and Polar Path compass system on Electronics Test Bench.

Complete operating instructions and blueprints are maintained on all test equipment and test tools designed and built by Convair. With few exceptions, they are available to applicable agencies.

TSTO NO.	SPECIAL TEST TOOL
22-30308	VHF Navigation Systems
22-30323	Weather Radar Systems
22-30325	SELCAL Units
22-60501-3	Bendix PB-20G Autopilot & Compass
22-60501-4	Sperry SP-30 Autopilot & Compass
22-91170	Modified C-10 Compass Swing System



EX Electrical Connectors

Assembly and Installation

EX type electrical connectors are designed for use in areas where high temperatures are encountered and expeditious repairs and replacements may be desired. The units can be quickly assembled and disassembled, and single contacts can be individually replaced without replacing the entire electrical connector.

The harness wires to the *EX* unit are fastened to the contacts by crimping rather than by soldering. This feature insures reliable contact in areas where elevated temperatures might exceed the melting point of the solder. Contacts are retained within the connector body by an insert material of heat-resistant silicon rubber. A compression nut (end bell) at the back of the connector body compresses the silicon rubber insert to form a moisture-proof seal. The rubber insert is not to be removed from the connector body.

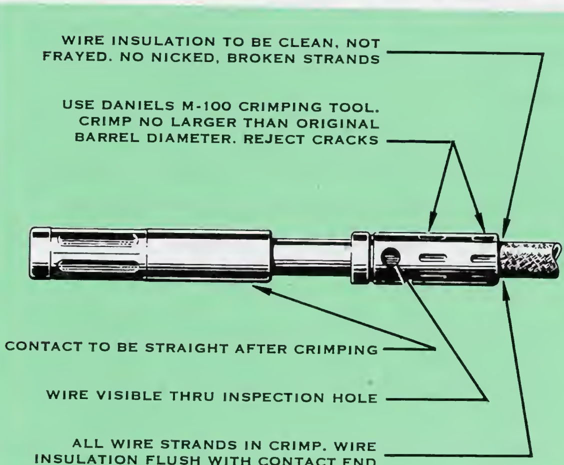
By employing the right tools for the job, assembling and servicing the *EX* electrical connectors can be accomplished with a minimum of time and effort. Daniels M-100 crimping tool is recommended for crimping the contacts; a Cannon insert tool is used for inserting the contact into the silicon rubber insert.

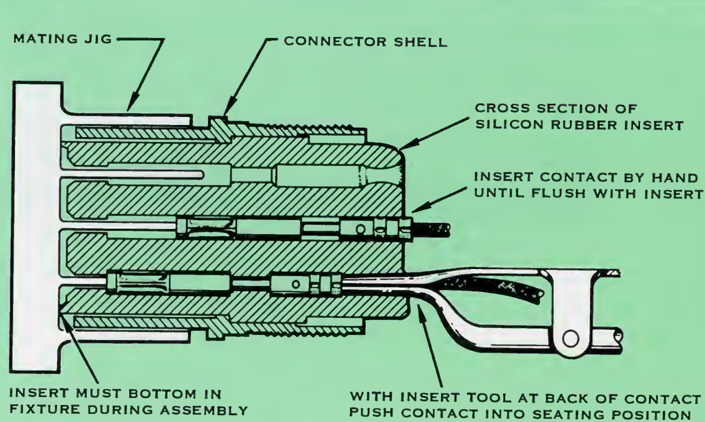
During assembly, it is important to keep the contacts free of grease and oil, because silicon rubber inserts become extremely "slippery" when in contact with lubricants, and lose their retaining qualities.

Before inserting wire into a contact, insulation should be stripped approximately ¼ inch from the end. The insulation should be cut clean, and wire strands should not be nicked or broken.

The contact is inserted into the appropriate die cavity of the crimping tool where it is held securely with its shoulder against the stop. Wire is then inserted into the contact with the insulation butted against the contact end, and the contact is crimped.

In photos from top to bottom: Contacts are fastened to wire ends by crimping tool. Connector is positioned on mating jig. Contact is pushed into insert with inserting tool.





To meet specified requirements, pull tests should be made to determine the tensile values of crimped contacts. During inspection, wire should not be bent at its connection to a contact.

Proper positioning of the contacts in the silicon rubber insulator may be determined by measuring from the face of the insulator to the tip of the contact. This dimension should be .200 for the red insulator, and .080 for the green insulator.

A mating connector, or locally manufactured jig, of the correct size is used as an aid in assembly. A Cannon insert tool (035649-0000) and a strap wrench are also used.

The connector is placed on the mating jig and pushed all the way to the bottom. The contacts are inserted in the insert openings (in planned sequence) until the socket contacts rest securely on the fixture pins. They are then pushed down by hand until they are flush with the back of the insert. The wire insulation at the back of the contact is gripped with the insert tool, and the contact is pushed into seating position. The inserting tool is then withdrawn.

The connector is sealed with a plastic compressor ring and with an end bell that is screwed on with a strap wrench. When properly positioned, the contact is firmly seated in the insert.

If the contact is clean and the end bell of the connector unit is tightened, the assembly should remain trouble-free indefinitely. For maximum retention of the contacts, all holes should be filled with contacts, and with plastic or wire plugs.

Contacts should always be inserted from the back side of the connector and should never be pulled through the insert from the inside. When disconnecting the plug, the connector body should be pulled — not the wiring harness.

By exercising reasonable care and observing the following rules, *EX* electrical connectors should give trouble-free service for the life of the wiring.

1. Wire should be stripped, leaving a clean insulation cut with no nicked or broken strands.

2. After crimping, all contacts should be checked for neat application and to insure tightness of the wire.

3. Contacts with flashings exceeding the original diameter of the contact should be rejected and the crimping tool checked.

4. Wire insulation should butt up against the end of the contact.

5. Contact barrel should not be split.

6. There should be no lubricant on the contacts or on any part of the connector assembly.

Before sealing, all connectors should be inspected for 1) proper seating of contacts, 2) damage to the insert material, 3) frayed wire insulation, and 4) lubricant on assembly.

After sealing, torque lacquer should be applied to the end bell and plastic compressor ring. If torque lacquer indicates that seal is broken, the connector assembly should be reinspected.

Null-Field Static Dischargers

Numerous null-field static dischargers are installed on the wing and horizontal and vertical stabilizers of Convair 880/990 jet airliners to reduce the noise, and increase the range of low frequency radio receivers. The range of low frequency receivers, such as the automatic direction finder, are increased as much as four times — from 10 to 12 miles up to 40 to 50 miles.

Low frequency radio receiver noise and the resultant restricted range is usually caused by precipitation static or engine exhaust gas charges. Precipitation static is primarily due to triboelectric charging (resulting from friction) that occurs when two dissimilar materials contact each other and then separate — as when hair is combed, or when an aircraft flies through precipitation.

When precipitation particles, dust, and other objects in the air collide with the airframe, the engine exhaust ions are freed by combustion heat, and the aircraft tends to acquire an electrically-charged (unbalanced) condition. Engine exhaust gas ions, as well as free ions loosed by impact, are caught in the airstream and swept away. When escaping ions fail to recombine, an electrical charge builds up on the aircraft until the surrounding air is ionized (forming corona) to provide a path to replace them.

Corona, often observed by pilots as purple arcing, and referred to as St. Elmo's fire, is the discharge of electrical current into the surrounding air when the electrical field at the object surface exceeds a critical value. Corona discharges occur as very rapid short pulses of current, and produce a noise spectrum containing considerable energy at low radio frequencies. Unless controlled, they blanket desired signals.

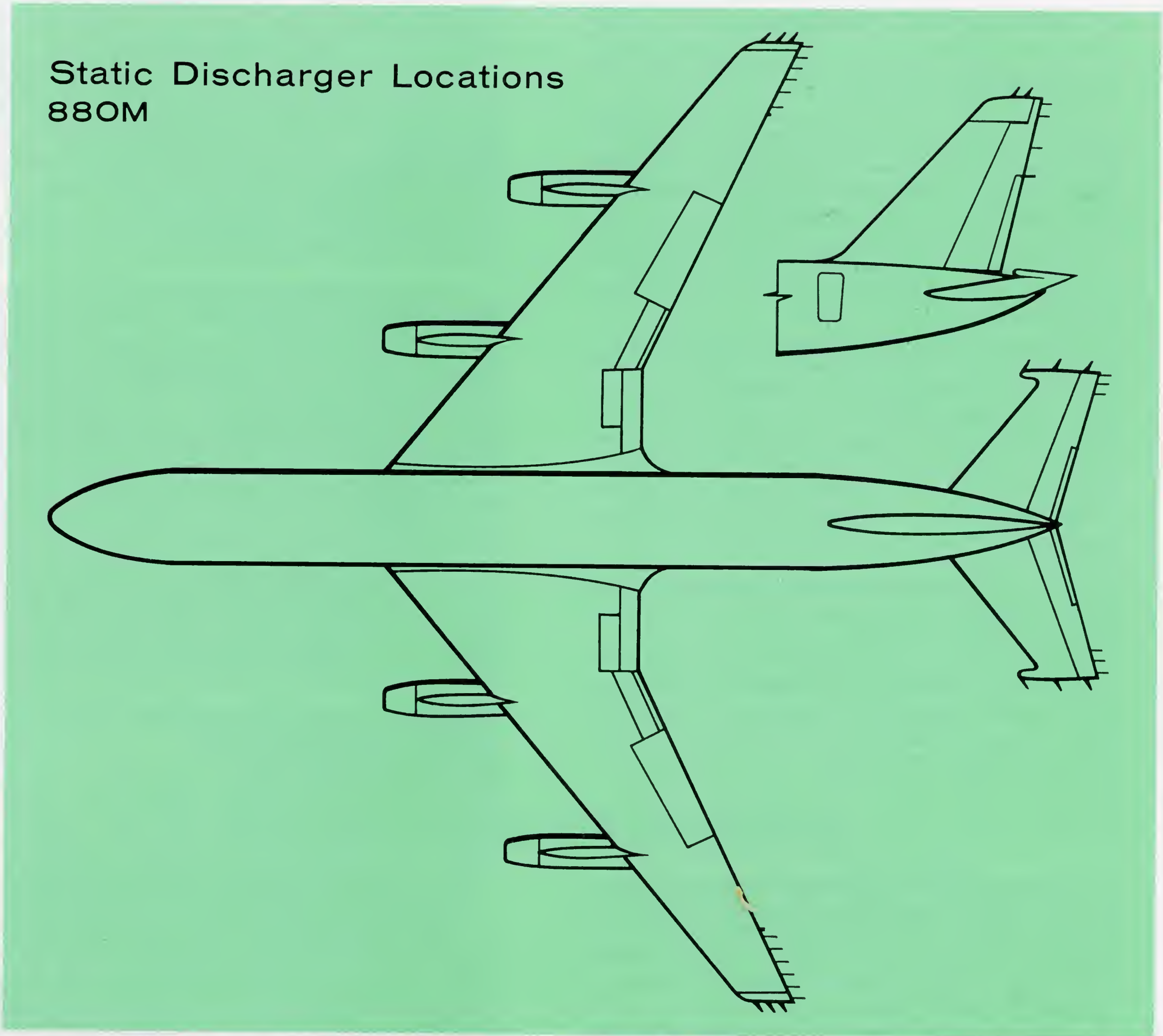
Electrical charges acquired by aircraft, and the resultant corona discharges, cannot be prevented. It is possible, however, to modify the fields in the discharge region to provide points that will correspond to zones of zero radio frequency, coupling with respect to the susceptible antenna system. This is the function of the null-field discharger.

Two types are in use on Convair 880/990's — a slender pencil-sized model for trailing edges; and a shorter size, resembling a vortex generator, for wing and empennage tips.

Sharp tungsten needles extend from an area near the discharger tips and at right angles to the body. The tip radii of these needles are kept very small so that the corona threshold voltage will be correspondingly low. This feature assures that the discharge will occur only at these control points.

The dischargers are installed in special mounting flanges attached to the airplane surface. The flanges are riveted to the skin or bonded by means of an electrically-conductive plastic adhesive. The recommended adhesive is available through Granger Associates . . . No. 610-1016 for one-ounce kits, and No. 610-1017 for half-pound lots.

(see next page for location of dischargers)


Static Discharger Locations
880M


WING
AND
EMPENNAGE
TRAILING EDGES


WING
AND
EMPENNAGE
TIPS

The Constant Speed Drive

A major advance in aircraft electric power systems made possible by a breakthrough in mechanics

Constant speed drives of the type that drive the a-c generators in the Convair 880 and 990 aircraft have a special interest for those with a mechanical inclination. They are the first effective solution of an engineering problem as old as machinery. Many partial solutions have been worked out, but no real answer has been found until recently.

The problem is to make a power transmission unit whose input shaft may revolve at variable speed, but whose output shaft speed will remain constant, regardless of load. When a-c generators are to be operated in parallel, as they are in the Convair jet airliners, the speed must be constant within narrow limits, no matter where the pilot may set the engine power lever or what sudden current supply he may demand when he operates a switch.

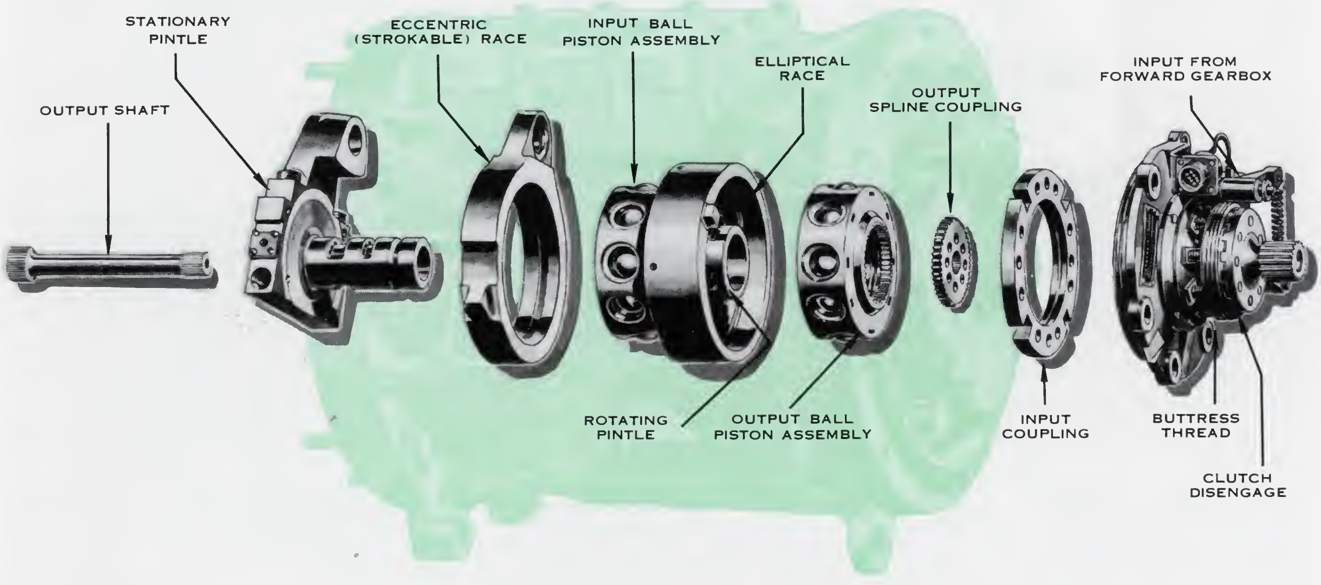
To make clear what a constant speed drive must be designed to do, imagine one installed in an automobile. It would replace both clutch and transmission; the engine would turn the input shaft, the output shaft would turn the wheels. The CSD would be set for 10 mph and engine idle speed adjustment would be set fast enough to supply a surplus of power.

When the driver starts the engine, the car will move off smoothly until it reaches 10 mph. Then, uphill and down, on the highway or in a mudhole, the wheels will turn at 10 mph. Lift the car off the ground and the wheels will keep turning steadily; drop it suddenly, and the tires will "burn rubber"—losing ½ mph for an instant, but picking up again to 10 mph wheel speed before the car has had time to move from the spot. Meanwhile, the driver sits and "guns" the engine to a roar or lets it "lug down" almost to stalling. Whatever he does, the engine will drive him up the steepest grade, on glare ice or through deep sand, at never less than 9.9 or more than 10.1 mph.

Such a transmission obviously represents an advance far beyond the contemporary automobile automatic transmission, which is regarded by the average motorist, with some justice, as already a pretty complicated gadget. Adding more complexity to the automotive type of transmission, with even more planetary gears and clutch transitions, could never meet the a-c generator requirements for high-speed jet aircraft. What was required was an engineering breakthrough.

The General Electric CSD unit in the 880 and 990 with far fewer parts and much less weight, holds the Convair transport a-c current at 400 cps ±1% (6000 generator rpm ±1%) with engine rpm from idle to takeoff (approximately 4500 to 7680 rpm) under electrical loads varying from 0 to 40,000 volt-amperes—equivalent to a 64-horsepower load.

The CSD is a hydraulic unit, mounted at the aft face of the forward engine gearbox, with the generator attached at the aft face. The basic mechanism is built around the ball piston design that is utilized in many high-speed high-pressure hydraulic pumps. Cylinders are radially machined into a cylinder block rotor that revolves on a pintle; the pistons are free-moving precision steel balls. The balls are moved by revolution of the rotor within an eccentric, or elliptical, race. Ports at the inner ends of the cylin-



Exploded view of constant speed drive transmission unit

ders, and on the outer surface of the pintle, admit or vent hydraulic fluid to or from the cylinders, depending on the angular positions of the rotor with reference to the pintle (see drawing).

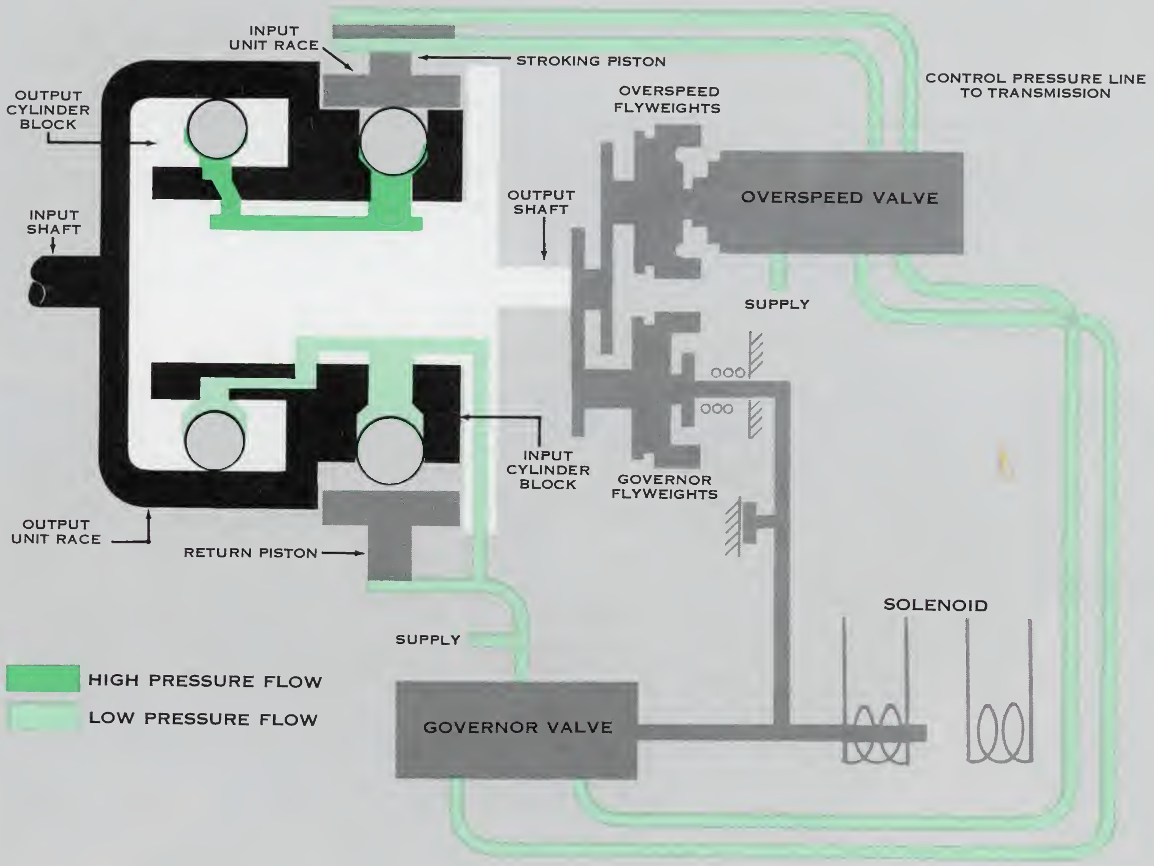
Forcing fluid through such a pump in reverse flow causes the pump to function as a motor. The pressure of the fluid forces the ball against the eccentric surface of the race, with a resultant torque moment that moves the rotor within the race.

There are two such ball piston assemblies in the General Electric CSD unit. One rotor, containing seven 1-inch cylinders, is driven by the input shaft; the other has nine ⅞-inch cylinders and is splined to the output shaft. The input race is circular and is positioned eccentrically, so that the assembly is a variable-displacement pump. The output assembly race is elliptical, so that the assembly makes up a fixed-delivery pump. The fluid is MIL-L-7808C lubricating oil, identical with that used for engine lubrication, and is stored in a separate compartment of the engine oil tank.

To understand just how it functions, a glance at the exploded view of components on page 149 will show some essential features. An important item to bear in mind is that the input rotor, the output (elliptical) race, and the output rotor pintle may be considered one integral part; output race and pintle rotate along with the input cylinder block rotor at input rpm. Input race and pintle are non-rotating. The input race is mounted on a pivot and may be moved to either side of center; flow is therefore reversible, depending on which side of center the eccentric race is positioned.

Position of the input ("strokable") race is set by cylindrical pistons mounted so as to bear on opposite sides of the race. One of these pistons functions only to maintain a constant high pressure; the other, termed

Simplified schematic of CSD transmission and controls

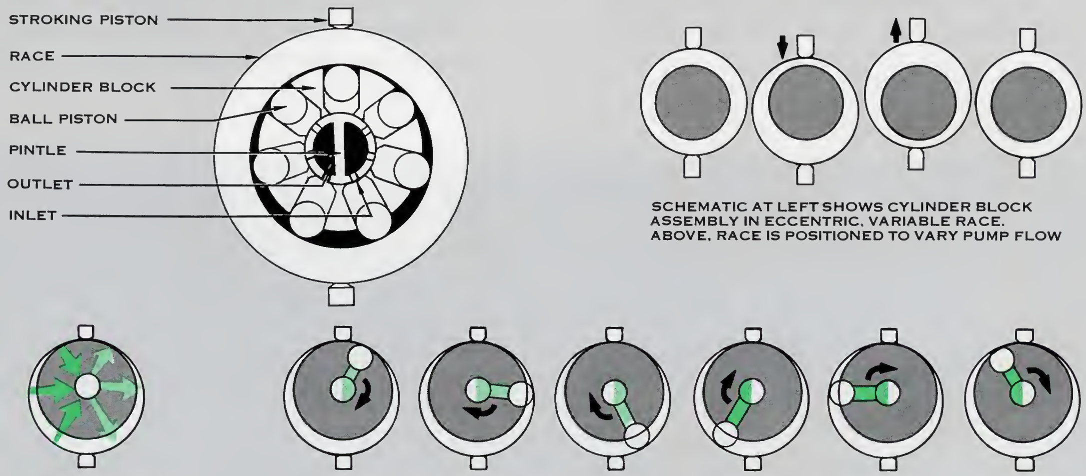


the "stroking" piston, is positioned by hydraulic fluid (CSD system oil) exerting pressure on either side of the piston head. Travel of the stroking piston is governed by two controls. One is a flyweight governor, responding to output shaft speed, and the other is an electrical solenoid actuated by load-sensing elements and so able to compensate for electrical load requirements.

With these principal elements of the unit in mind, it is possible to trace the mechanics of the operation. The two ball piston cylinder block rotors are linked hydraulically through the output (rotating) pintle that turns with the input rotor. The usual explanation is that one of the two hydraulic units functions as a pump and the other as a motor; which one is pumping depends on which is turning slower. This is true in terms of fluid flow, but may be misleading, since the input assembly always drives the output, regardless of direction of fluid flow. Pumping action of the input assembly occurs when power is applied to the input rotor; pumping action of the output assembly occurs when the elliptical race is driven faster than its rotor.

While it might seem logical to begin with the engine at zero rpm, explanation may be simpler by beginning with zero fluid flow condition. This is the status when engine and generator are both turning at 6000 rpm, a transient condition that normally exists only during acceleration and deceleration. At that instant, the input race is centered, the input ball pistons are not moving in their cylinders, and there is no fluid flow to or from the output cylinders. Half the output ball pistons, being hydraulically connected to half the input cylinders, are therefore hydraulically locked at varying depths in the cylinders. The elliptical race, turning at input shaft speed, will turn the output rotor, and hence the output shaft, at the same speed as that of the input shaft.

Variable-displacement ball piston pump with eccentric race

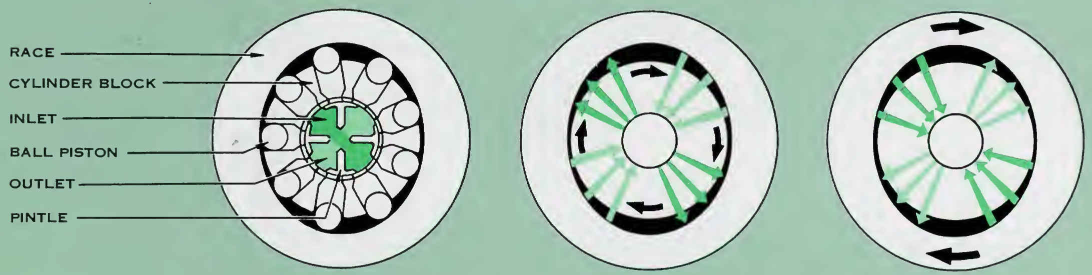


SCHEMATIC AT LEFT SHOWS CYLINDER BLOCK ASSEMBLY IN ECCENTRIC, VARIABLE RACE. ABOVE, RACE IS POSITIONED TO VARY PUMP FLOW

PUMPING, CYLINDERS RECEIVE FLUID, RIGHT, AND DISCHARGE, LEFT

DIAGRAM OF SINGLE CYLINDER ACTION SHOWS, LEFT, THREE POSITIONS OF INTAKE STROKE, AND RIGHT, ACTION OF PUMPING STROKE. PINTLE IN CENTER HAS PORTS TO ADMIT AND DISCHARGE FLUID.

Fixed-displacement ball piston pump with elliptical race



BALL PISTON IN ELLIPTICAL RACE MAKES TWO PUMPING STROKES EACH REVOLUTION. WHEN OPERATED AS MOTOR (CENTER), FLUID FORCED THROUGH HIGH-PRESSURE PORTS TURNS ROTOR WITHIN RACE. RIGHT, PUMPING ACTION WHEN RACE IS REVOLVED AROUND ROTOR

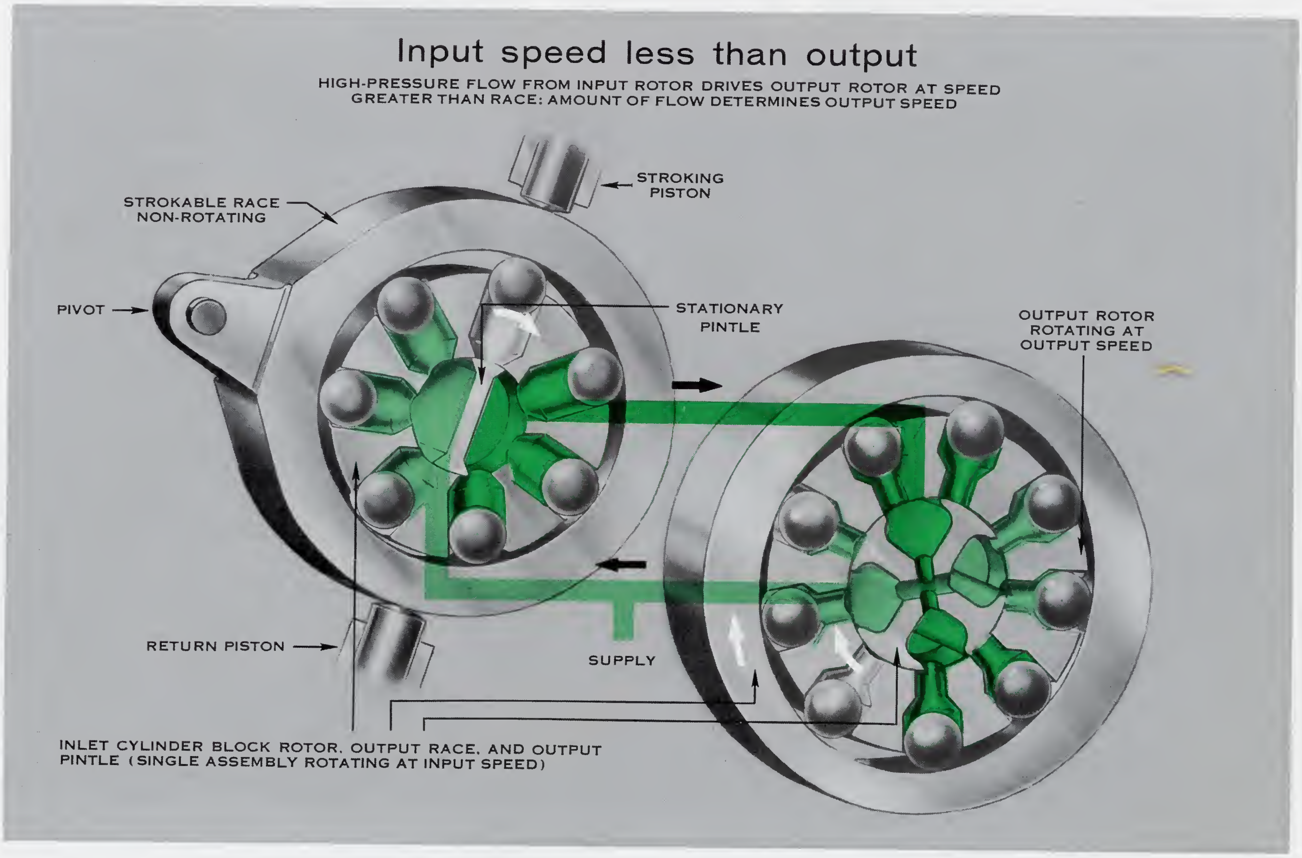
Now, assume that engine rpm drops. As soon as the flyweight governor senses a speed decrease below 6000 rpm in the output shaft, it will port fluid to the stroking piston and the strokable (input) race will be moved toward the position indicated in the drawing on page 150. Ball pistons will pump fluid into the output cylinders; the pressure on the output ball pistons will force the rotor to move faster than the race, and output shaft speed will increase until it reaches 6000 rpm. The governor will hold this speed by regulating fluid flow to position the strokable race.

Assume that engine speed increases above 6000 rpm, the normal operating condition during flight. Then the governor will move the input race toward the position indicated in drawing on page 153. Fluid will begin to flow from output to input cylinders. Since the load of the generator is a constant drag on the output shaft, the elliptical race will begin to slip past the rotor, by this action moving the output ball pistons so as to the pump fluid back toward the input cylinders. The differential in output and input speeds will be limited by the rate at which the input assembly pumps fluid—or, rather, permits fluid to pass—back into the supply, and this rate will be governed by position of the input race. As engine speed increases, the governor will displace the race more and more, permitting the input assembly to slip more rapidly past the output rotor.

It is evident that the governor must furnish sensitive speed control. In principle, it is a standard flyweight type with a reference spring, operating a servo valve that ports fluid to one or the other side of the stroking piston. The governor is driven by an accessory drive set of gears mounted within the CSD case at the output end.

A-C generators operating in parallel not only must maintain a synchronous frequency—i.e., identical rotor speeds—but also must share equally in bearing the electrical load. To provide the fine control required for this load division, an electrical control is superimposed on the governor control, by means of a load-biasing solenoid that acts directly on the servo valve. The solenoid is operated by the load controller, a sensitive "black box" unit that senses real load on the generator. Load controllers for all generators are electrically interconnected; when load on one generator increases or decreases relative to the loads on the others, the load controller directs an impulse to the solenoid to provide more or less CSD output power.

For such a high-speed heavy-duty transmission, safeguards are necessary. The CSD is a linkage between a power source that, for this purpose, may be considered unlimited, and a generator whose drag may exceed 100 horsepower momentarily. There are four safeguards within the CSD unit to protect the CSD and/or the generator: an underspeed-overspeed assem-



bly, an overrunning clutch, a disengage clutch, and a shear section.

Along with the control governor is a separate independent overspeed governor, operated by a gear on the output shaft. A second flyball governor, in the same housing, actuates a switch that cuts the generator off the line if speed falls below limits. The overspeed governor, if output speed should exceed approximately 7200 rpm, actuates a separate overspeed servo valve that applies an overriding hydraulic pressure to the stroking piston, forcing the drive to an underspeed condition. The underspeed switch then cuts the generator off the line. The servo valve will reset automatically when CSD speed falls to almost zero, as on engine shutdown.

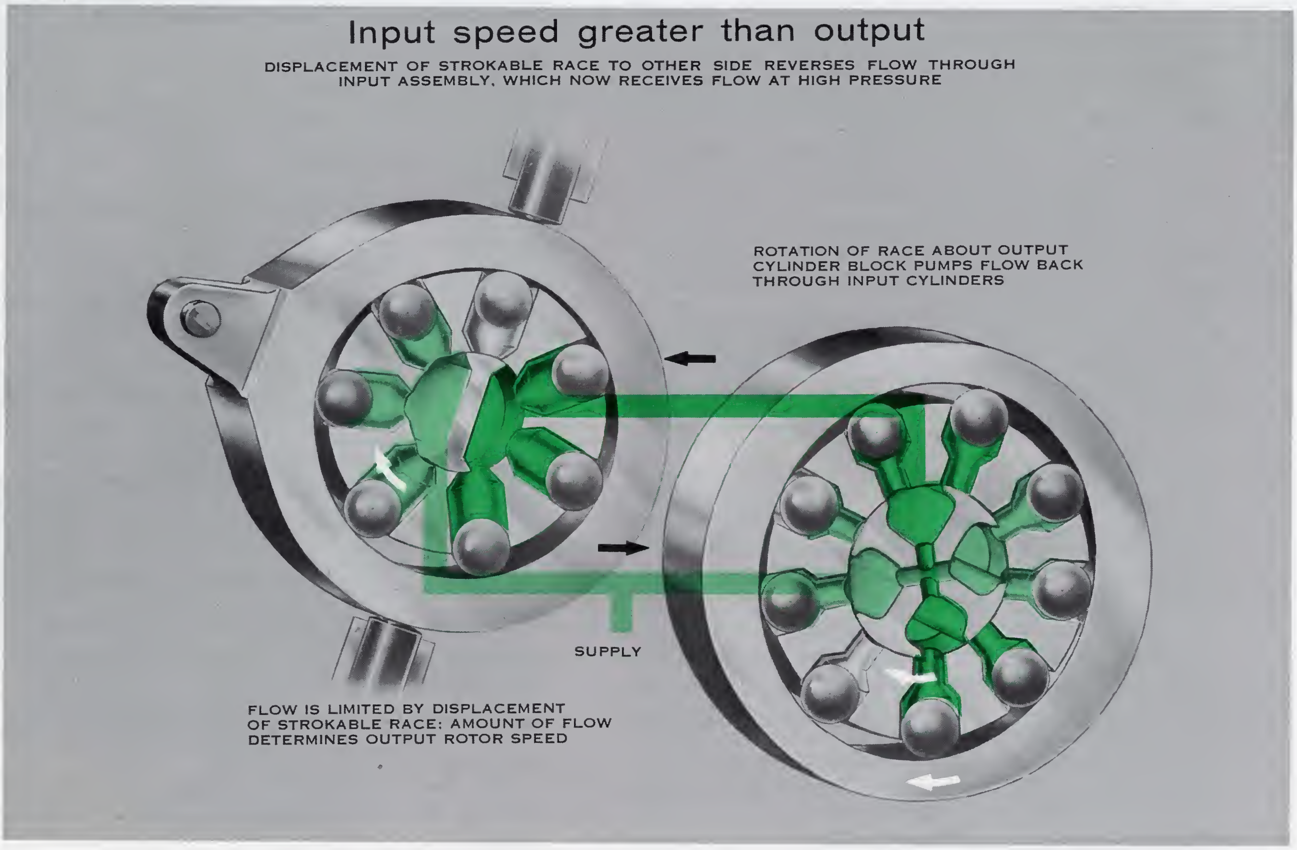
The overrunning clutch is in the output shaft assembly. Should the generator attempt to motor the CSD, the generator will be automatically disengaged.

On the input end is a quick-disconnect assembly that can be operated from the flight compartment. The assembly consists of a mesh clutch, one plate of which moves on a splined shaft. Normally, the plate is meshed with the drive assembly. On its circumference is a coarse buttress thread. A sector arm, operated by a solenoid controlled by a switch on the flight engineer's panel, can be dropped into the buttress thread, and the sliding clutch plate will be driven back to disengage from the drive plate. This disconnect cannot be reset until the engine is stopped and the sector arm pulled out manually to allow the plates to mesh.

The shear section is part of the CSD input shaft. It fails under excessive torque, as a final protection against major malfunction in the drive or generator.

A thermal switch in the CSD case illuminates a red warning light on the flight engineer's panel, should CSD oil temperature become excessive.

The CSD oil system requires both supply and scavenge pumps. They are in one housing and are driven by the CSD accessory drive assembly. Both are positive-displacement type. The supply pump maintains 140 to 150 psi in the CSD; the scavenge pump maintains 110 to 130 psi in the return lines and the reservoir. A 10-micron filter in the supply lines removes dirt or metal dust before the oil is delivered to the ball pistons. The return supply to the reservoir passes through an oil-to-fuel cooler. A valve opens and closes automatically to maintain oil temperatures at approximately 240° to 275°F.



Audible Warning System

In the Convair 880, a horn and two bells are installed to warn the flight crew if certain controls are not properly set or if immediate attention or action to some function is required.

The automatic warning horn has three distinct sounds: 1) a continuous note; 2) equal on-and-off sound; and 3) a repeated long on and short off note. These three different horn sounds advise the crew of the following conditions.

Continuous Sounding Horn. With the airplane on the ground, this sound indicates that landing gear lever is not in the locked (detent) position, or the landing gear lock solenoid (at landing gear handle) is unlocked. When airborne, the continuous sound indicates that any power lever is retarded below 75% rpm and any one landing gear is not down and locked. The horn will also sound if flaps are extended more than 43° when landing gear is not down and locked. (An interrupter switch enables the pilot to silence the horn if desired, but when power is advanced, the horn is automatically reset for warning.)

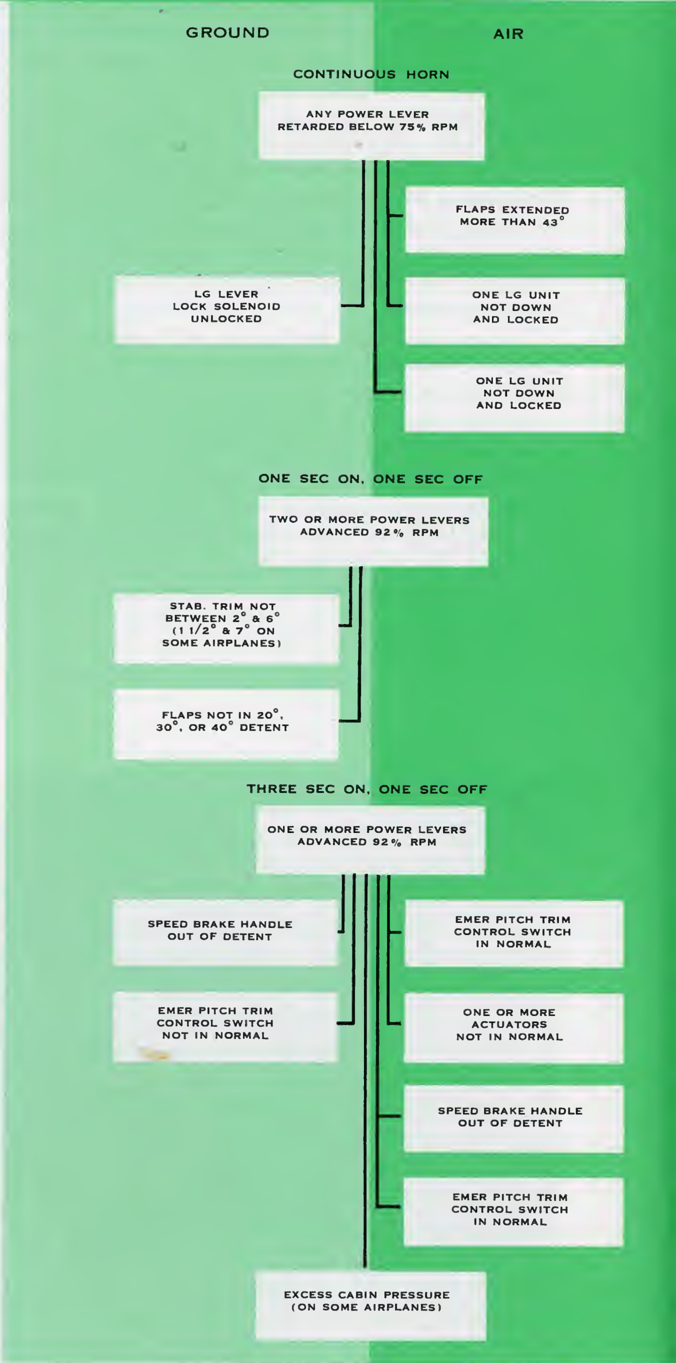
Equal-On-and-Off Sound (1 second on, 1 second off). On the ground, this intermittent sound indicates that two or more power levers are advanced 92% rpm, and the stabilizer is not positioned for takeoff trim (not between 2° and 6°; 1 1/2° and 7° on some airplanes), or the flaps are not in the 20-, 30-, or 40-degree detent position.

Long On, Short Off Sound (3 seconds on, 1 second off). On the ground, this warning will sound if two or more power levers are advanced 92% rpm, and either the speed brake handle is out of detent, or the emergency trim control switch is NOT in normal (either set for pitch up, or for pitch down).

When airborne, the sound indicates that two or more power levers are advanced 92% rpm with the emergency pitch control switch in normal, but either the speed brake handle is out of detent or one or more of the actuators is not in normal position. The horn will also sound any time that excess cabin pressure should develop.

Two different sounding bells supplement the horn warning systems.

Continuous Sounding Bell. One of the warning bells, located overhead in the flight compartment, sounds with a steady ring any time an overheat condition or possible fire exists in an engine pod. When the bell sounds, and either of these conditions exist, a red light will appear in the engine fire-pull handle to indicate the engine pod affected. A steady light and bell indicates a fire warning, and an intermittent light and steady bell indicates an overheat condition. By proceeding with the fire control procedure for this engine, it can be determined whether the overheat is caused by a leak in the hot section aft of the vertical firewall or by an actual fire, forward of the vertical firewall. Extinguishing action will be necessary.



Intermittent Bell. In flight, a bell, located forward and to the left of the pilot, will ring intermittently if airplane speed nears the VNE/MNE limitation of the airplane. This bell, commonly referred to as the "Veenie Meenie" bell, is a part of the Mach/Airspeed Never-Exceed Warning System.

On some Convair 880's, a gong gives an audible warning of terrain obstruction within a pre-selected range.

Simmonds Fuel Gaging System

880/990

The Convair 880 jet airliner carries up to 82,000 pounds of fuel — approximately seven times the Convair-Liner maximum. Fuel-to-payload ratio is correspondingly high, and accuracy in fuel gaging is correspondingly more important. When a jet transport pilot adds up his gross weight for a maximum-load takeoff, his percentage allowance for possible system error must be low; if it isn't, the error allowance may be in thousands of pounds rather than hundreds.

To prevent needless sacrifice of payload, and to make possible safe fuel scheduling in flight, the Convair 880 and 990 transports have gaging systems as accurate as they can possibly be made, in the present state of the art. Where the "Mil-spec" design requirement (MIL-G-7818) for a twin-engine airplane was approximately 3½% maximum system error, the objective for the Convair jet aircraft is an accuracy within 1%.

This is a task of formidable complexity. Gaging systems, almost universally based on electrical capacitance, depend on dielectric and chemical constants that are never quite constant. Quantity gages depend on depth gages; in a wing tank, an inch difference in fluid level at midpoint may represent 200 gallons, at another point 50 gallons. Irregularly shaped tanks require multiple sensing points. Airplane attitude and wing deflection complicate the problem.

The gaging systems worked out for Convair 880 and 990 transports are supplied by Simmonds Aerocessories, Inc. They provide: (1) flight compartment readings for fuel quantity in each tank, and total fuel aboard; (2) wing refuel panel indicator readings of equal accuracy for quantity in each main-replenish tank system; and (3), an automatic cutoff in connection with the pressure refueling system for filling each tank pair to a specified level.

BASIC CIRCUIT

There are a total of 48 capacitance-type probes in "880" wing tanks, and 4 in the center section fuel cells. In the center section fuel cells of the "990" are 6 probes, plus another 6 in the anti-shock bodies.

Each probe is "characterized" — individually profiled to match the tank contour. The probe consists of two concentric cylindrical tubes, separated by a comparatively large air gap.

Basic material of the tubes is epoxy-impregnated Fiberglas. The capacitative element is a silver surface film, deposited on the Fiberglas in a pattern that is generally spiral. Profiling for tank shape is effected during manufacture by a photochemical process. Holes through the outer tubes allow free flooding of the gap between conducting surfaces.

Electric power utilized is 115-volt 400-cycle ac. The dielectric constant of petroleum is approximately twice that of air. Since ac current flow through a capacitor varies directly with dielectric constant, current through the probes is a function of the height of the fluid level between inner and outer tubes.

All probes in any one tank — as many as nine in outboard main tanks — are paralleled. The sum of these capacitances, as measured by the total current through the probes, is thus a measure of the amount of fuel in the tanks.

The method by which current flow through the probes is interpreted in a reading on an instrument dial is on the principle of a continuously rebalanced inductive bridge circuit, in which capacity of the tank unit is constantly compared with a fixed-capacitance reference capacitor. The voltage signal resulting from the difference in capacitance is amplified to operate a motor-driven potentiometer, which restores the inductive balance, and at the same time operates the indicator mechanism.

Flight compartment indicators in the 880/990 have a 180° pointer dial in the top half of the face. More precise readings are given on counters in the lower half of the face. The three-digit counters show fuel quantity in 100-pound increments. The motor that operates the potentiometer wiper through a gear re-

duction train also drives pointer and counter through the same gear mechanism.

There are five such indicators on the "880" flight engineer's panel, one each for No. 1, No. 2, No. 3, and No. 4 pairs of main and replenishing tanks and one for the center section fuel cells. Each indicator unit includes its bridge calibrator and amplifier. A three-position switch, just above the bank of indicators, permits reading quantity in main tanks, replenish tanks, or the totals in both. Normally the switch is in TOTAL position. At MAIN position, the switch substitutes an empty-tank capacitance for the actual replenishing tank capacitance, and vice versa.

The flight engineer's indicators in the "990" are governed by a four-position switch; the extra position is for the anti-shock bodies.

The indicator unit includes a second potentiometer, operated by the rebalancing motor. Output from this potentiometer goes to the totalizer circuit. Wing refuel panel repeaters are operated from the rebalancing potentiometer.

In the "880" and in some versions of the "990" a totalizer indicator is at the lower left corner of the center instrument panel. Signals from the separate tank indicators are added in a summation bridge assembly, housed within the indicator. Repeater gages for the "880" are on refuel panels on outboard side of inboard pylons, and duplicate exactly the TOTAL readings on the flight engineer's panel.

"Full" and "empty" adjustments are provided at each instrument. The repeaters require "full" adjustment only.

COMPENSATOR CIRCUIT

The dielectric constant of petroleum fuels is to some degree a function of density. Capacitance gaging systems tend to be self-compensating for variation in temperature or relative densities of fuels; in general, the more dense the fuel, the higher will be the gage reading. Different lots of the same type of fuel, however, may vary in basic electrical characteristics.

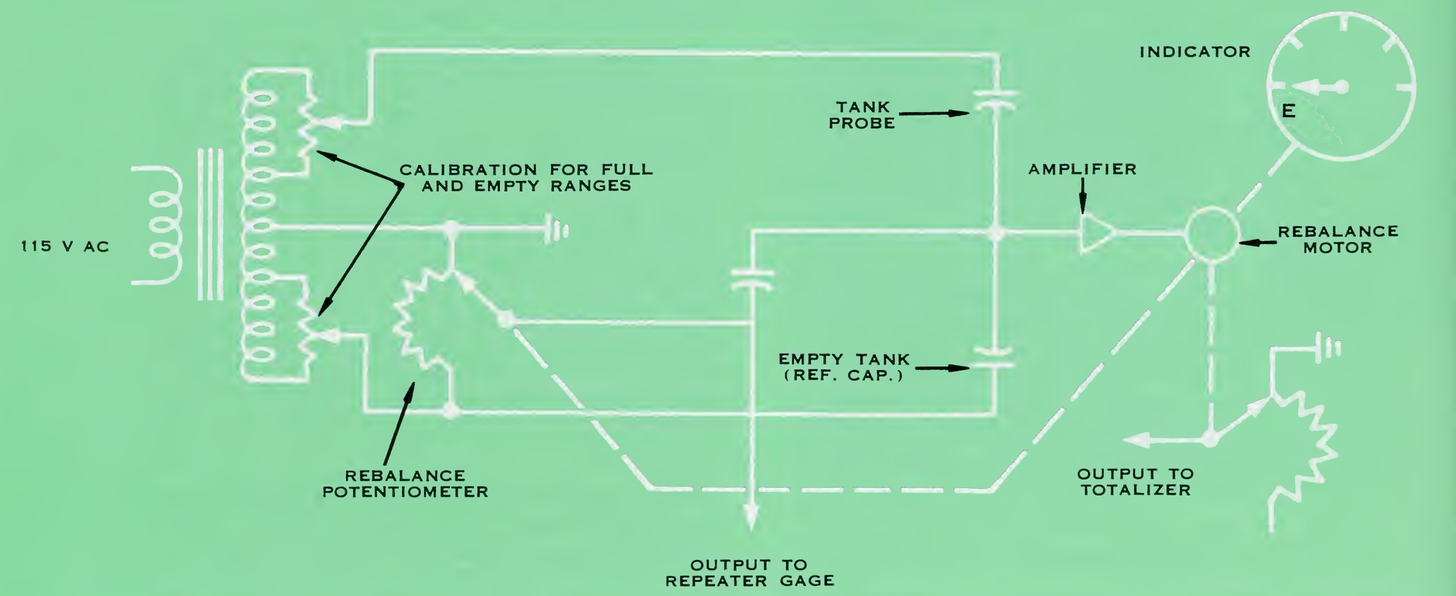
To reduce the error caused by varying characteristics of fuels, comparatively simple compensators are added in the 880/990 gaging systems. These are wire-wound capacitors, termed "monitors," mounted at the low level in each tank.

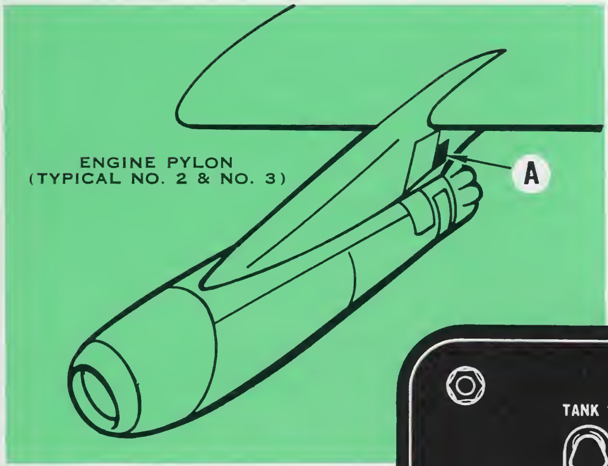
The monitor signal is inserted into the indicator inductive balance circuitry on the opposite side of the bridge from the probe signal. If the dielectric constant of a particular fuel is high, for example, the augmented probe signal would tend to cause a high quantity reading; but the opposing monitor signal will attenuate the probe signal, so that quantity readings will be virtually unaffected, within the range of dielectric constants of standard JP-4 fuels.

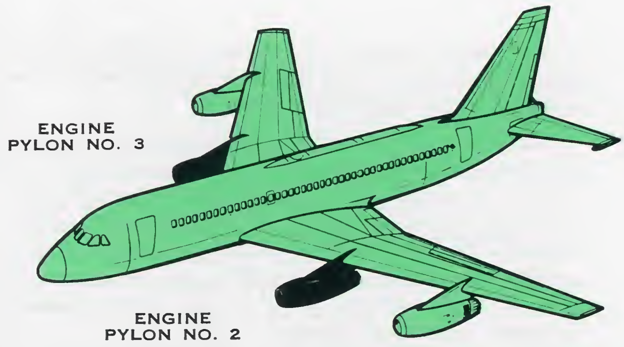
PYLON REFUEL SELECTION

Each refuel panel, pylon-mounted in the "880" and near the wingtip on the "990," has two repeater indicators, one for each of the two pairs of main-replenish tanks in that wing. The engine pylon #2 panel has a repeater indicator for the center section fuel cells. Around the periphery of each dial is a pointer that can

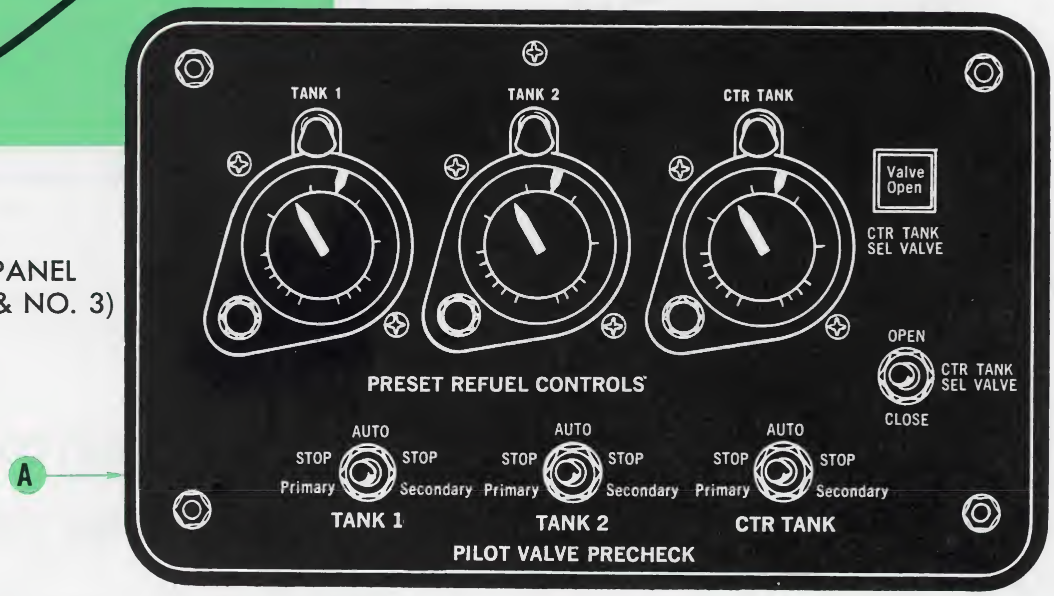
BRIDGE CIRCUIT - EMPTY TANK



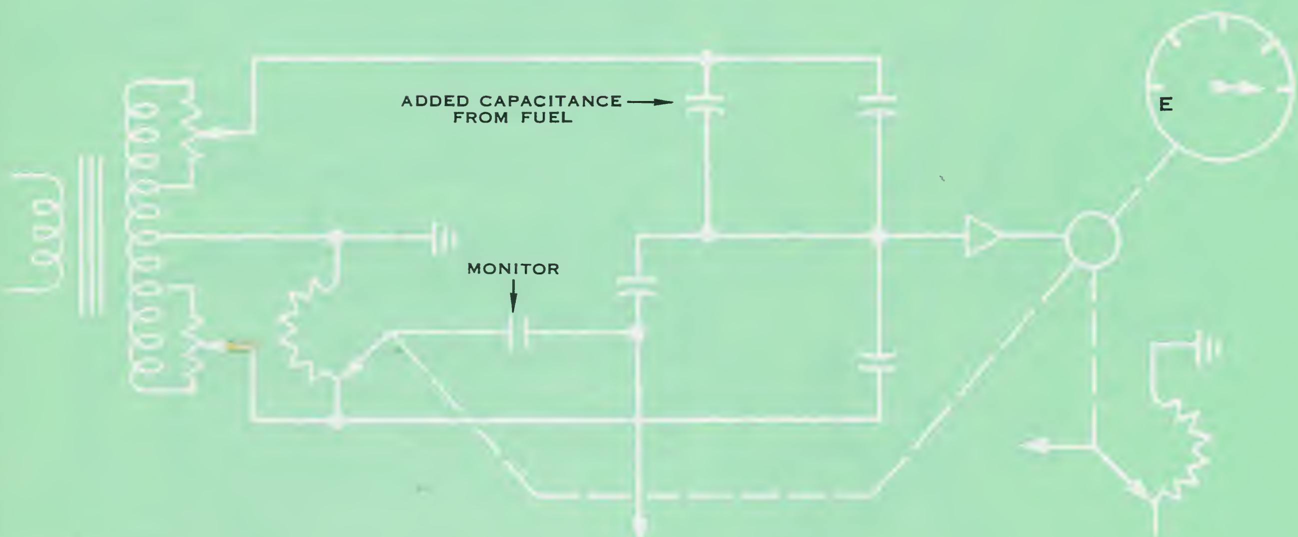




REFUELING CONTROL PANEL
(TYPICAL PYLONS NO. 2 & NO. 3)



BRIDGE CIRCUIT - FULL TANK



be set to stop refueling when preset to the desired fuel quantity. Operation of this shutoff mechanism can be traced in the valve system schematic.

There are four successive cutoff valves in the pressure line inlet, each springloaded to the closed position. The first is a check valve, automatically opened when the fueling line is connected. The fourth is a pressure regulator valve, opened by refueling pressure but designed to cut off flow, if pumping pressure is excessive. Between these two is a pair of shutoff valves, termed "primary" and "secondary."

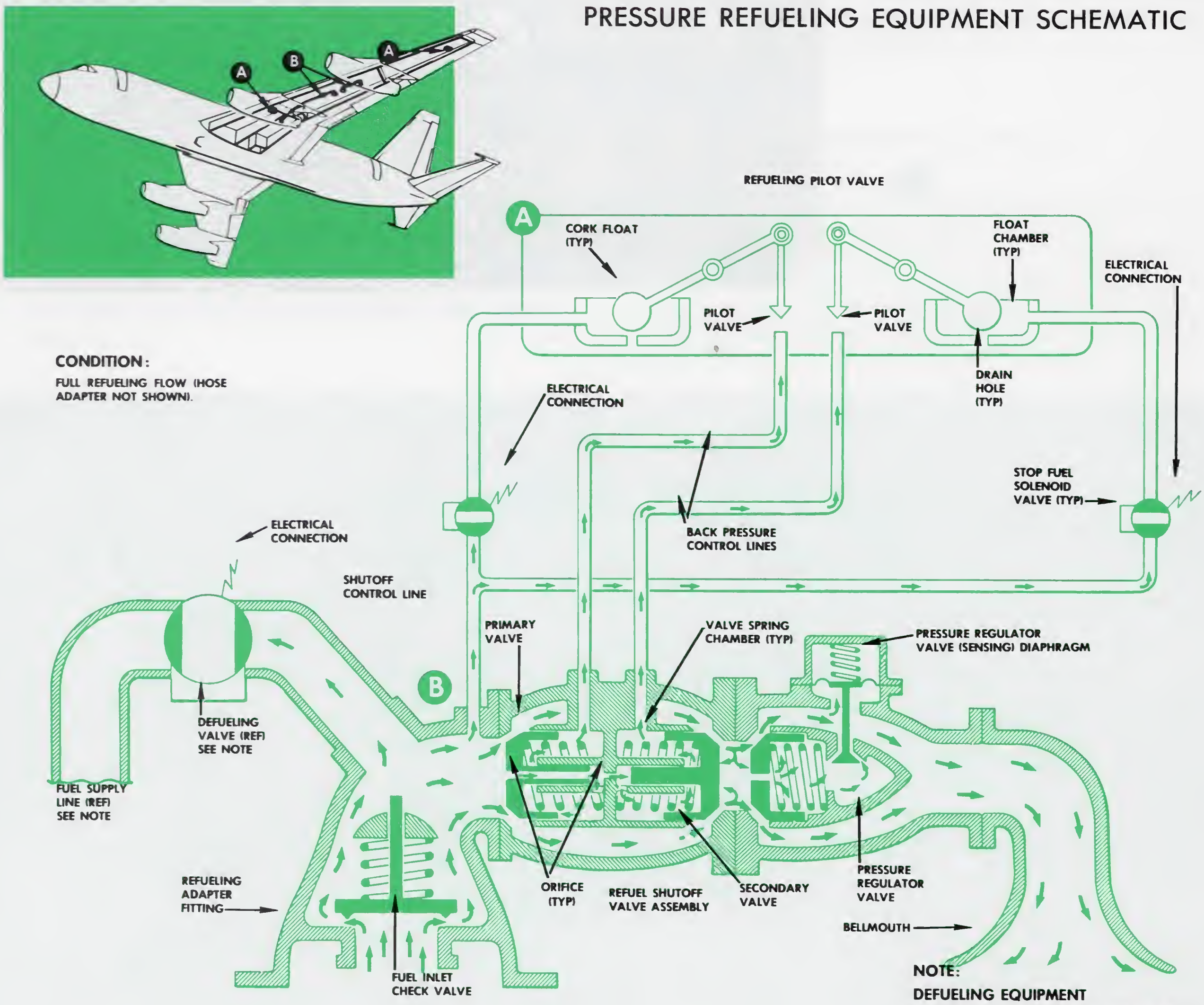
Fueling pressure is 50 psig. When pressure is directed against the faces of the primary and secondary poppets, they open and remain open as long as flow pressure on the face is greater than that inside the valve spring chambers. Bleed orifices through the poppets allow constant flow through the spring chambers and through tubing into overflow pilot valves.

The pilot valves are float-operated. The float chambers are connected via solenoid-operated valves to inlet pressure. The solenoids are connected to pointers on the indicator pointer shaft.

While the fuel flows, the solenoid valves are closed. When the indicator contacts close, both primary and secondary valves open the lines to the float chambers. The floats close the pilot overflow valves, and pressures equalize at the poppets. The spring-loading then forces both valves closed, and fuel flow ceases.

Beneath the indicators on the panel is a test switch marked "P" and "S," for primary and secondary shutoff valves. When refueling, the crewman should test both shutoffs as soon as flow starts. Drains in the float chambers will empty the chambers again in time for the automatic shutoff system to operate.

PRESSURE REFUELING EQUIPMENT SCHEMATIC



A pioneer in the design and development of integral fuel tanks since 1934, Convair has progressively led the way in design improvement until today the integral wing fuel tanks being produced to support the fuel system of the new Convair 880 jet transport are among the finest components of their kind on any aircraft in the world.

The extremely long service life of these tanks in yesterday's aircraft and in currently operating Convair 240 - 340 - 440 type airplanes has conclusively proved the soundness of Convair design. Now a revolutionary new process utilizing structural adhesives has already assured the company of continued leadership in this field during the coming jet age.

Convair conceived an idea for improved integral fuel tank design employing structural adhesives as early as 1943. But the complex chemistry involved, coupled with huge expenditures for research, held up the development of adhesively-sealed fuel tanks until 1951. At that time, the company embarked on a research program to develop a maintenance-free sealing system, employing structural adhesives, for use on the delta wing military aircraft then in a predesign stage.

THE SCOTCH-WELD ADHESIVE BONDING PROCESS - ITS USE IN CONVAIR 880 INTEGRAL WING FUEL TANKS

This research program involved five years of experimental work by Convair and several adhesive manufacturers, and proved Scotch-Weld adhesive film to be the answer.

The approach to the design problem set in action an extensive screening program to select an adhesive that could meet the following six design requirements:

1. It must be usable with JP-1 and JP-4 jet fuels.

2. Resistance to corrosive fluids such as hydrobromic acid and sulphur mercaptains, etc., was essential.

3. To restrain fuel from boiling at high altitudes, the adhesive must embody resistance to high pressures.

4. Resistance to temperatures ranging from —65°F to +250°F was mandatory.

5. It must be able to withstand structural deflections imposed on wings from dynamic loads of supersonic flight, and to withstand high-speed taxi runs over rough runways.

6. It must have high production adaptability to permit the use of semi-skilled mechanics for assembly work.

After building and testing small pressure boxes using liquid adhesives, the necessity for development of a dry structural film, which could be assembled in the seams of the fuel area, was apparent. This created a further need for development of a high-strength bond by heat curing. As a result, new design requirements became necessary.

The seam sealer must be a dry film capable of heat activation which, when cured, would afford a positive fuel barrier and develop sufficient bond strength to resist peeling action, especially at low temperatures. Normally, organic materials are subject to brittleness at low temperatures. The target load set as a goal was a minimum of 2500 psi shear strength at —65°F.

The application requirements had to be considered, such as 1) a curing temperature compatible with 7075ST aluminum, 2) clamping pressure not to exceed that gained from hand-driven rivets in minimum gage sheet aluminum, and 3) a curing time cycle consistent with the heat limits of 7075ST aluminum. ANC 5 Bulletin was used as a guide in selecting the heat range and time cycle for curing the adhesive.

The adhesive selected must maintain chemical and physical properties when subjected to aviation gasoline ranging from 115 to 145 octane, JP-3 and JP-4 jet fuels, JP-3 and JP-4 fuels with 30 percent aromatics added, and a mixture of salt water with hydrocarbons.

The sealant must be of a non-explosive material of low toxicity, with a shelf life consistent with normal production requirements and an application technique possible with semi-skilled workmen.

The bonding characteristic of the adhesive must afford positive, high-strength bonds to clad and non-clad surface-treated aluminum, including rolled sheet, extruded sections, and pressed forgings.

Strips of dry Scotch-Weld bonding film are placed between faying surfaces and structural members.

The structural flexibility of the adhesive must be consistent with the maximum deflection of the airplane without peeling or cracking, and the sealant must be able to withstand an internal pressure of 15 psi.

The adhesive must be compatible with Thiokol type fuel sealing compounds and be capable of repair with Thiokol at any time during its service life.

The adhesive must resist deterioration when exposed to ozone, fungi, bacteria, and water and acids common to fuel stowage.

With the establishment of design criteria, a survey was made to locate suppliers who could produce an adhesive film to meet the necessary requirements. During preliminary product screenings, the elevated temperature effect on the adhesives was determined by alternate exposures to +250°F and +180°F for cycles of five minutes at each temperature. Total time at +250° was 400 hours. Results were shown in terms of shear strength versus time exposure to +250°F in 50-hour intervals.

After these preliminary screenings, the most promising adhesives produced by several different companies were put through a further series of tests, using JP-3 fuel, at various pressures and temperatures.

Specimens for "puffer boxes" (internal pressure boxes) were fabricated, using 7075ST aluminum. Adhesive was clamped in seams employing only the pressures derived from hand-driven 2024ST DD rivets. The adhesive was cured at temperatures compatible with heat limits of 7075ST.

The design of the "puffer boxes" was established to accommodate the pressure plates, and a standpipe pressure vesssel was developed with air over water over fuel. Tests utilizing JP-3 fuel were conducted at 10,000 cycles, 0 to 15 and 0 to 25 psi, at room temperature and at —65°F, and at +250° without fuel.

At this stage of testing, Convair recognized the need for an improved rivet design which would provide necessary clamping pressure on the adhesive-filled seams and improve fuel sealing by use of a static seal under the head. A new rivet, known as the Straylor rivet, was tested and patented by Convair, and used in the F-102A. A similar rivet, also developed by Convair, is employed in the "880." It is installed in a drilled and counter-bored hole.

Rivet sealing studies during these preliminary tests were made with pressure plates, employing Straylor rivets. Reversal loads on attaching tee sections were applied and the pressure box was cycled at 0 to 15 psi pressure with JP-3 fuel for 10,000 load cycles.

Peel studies were also conducted on adhesive bonds. Specimens simulating typical skin-to-spar joints were tested in a standard tensile shear test machine to study skin deflection under load. Sufficient tension loads were applied to fail the specimens.

A full-scale test tank, 10 x 40 x 75 inches, was then fabricated, using Scotch-Weld, a 10-mil thick adhesive produced by the Minnesota Mining and Manufacturing Company, as a sealant. Because of its superior qualities, this film was selected for subsequent use in the F-102 and F-106 military aircraft, and is now being employed in the Convair 880 commercial transport.

The tank was then assembled, using Scotch-Weld AF-10 adhesive in each seam, and clamped in position by hand-driven rivets. The complete tank was heat-cured at +320°F for one hour. Following the curing cycle, gastight corners were injected with Minnesota Mining EC-1291 Thiokol, the void ends being capped with 2S aluminum plugs.

The test box thus constructed was cycled through torsional and bending loads simulating actual flight conditions, coupled with cycled pressure, and high and low temperatures ranging from —65°F to +240°F. As a result of this test program, a final design fuel-sealing system was established, employing Scotch-Weld AF-10 adhesive film, sandwiched between surfaces that were prepared with alodine 600 and Scotch-Weld prime.

To incorporate all of the design elements in an actual piece of airplane hardware for testing, Convair selected the forward wing fuel tank of the F-102 delta configuration. This final test was to prove the integral fuel tank sealing system to be effective and, at the same time, measure fatigue factors of wing-to-fuselage connections.

This wing specimen was fabricated in the factory, using typical production procedures. A fuselage section 16 feet long, common to the actual wing installation on the airplane, was constructed and used as a base mount for the wing tests.

The fuel tank was filled with JP-4 fuel heavily charged with red dye to facilitate checking for fuel leakage as the test progressed. For ambient temperature tests, the internal tank pressures were provided by regulated air pressure.

An overhead craneway structure facilitates movement of parts inside the Convair-San Diego Scotch-Weld building, eliminating hand contact.

For the cold portion of the test, the same basic equipment was used, with insulation added to the tank. The JP-4 fuel was cooled in an auxiliary tank by introduction of liquid CO_2 through a small orifice located in the bottom of the auxiliary tank. The cold fuel was then pumped through the test tank by a system of three aircraft type fuel pumps. Temperatures of the tank structures were determined by use of six copper-constantan thermocouples fixed to the wing skins. Internal pressures were controlled at 6 psig by maintaining a constant head of fuel in the auxiliary tank.

A moderate amount of difficulty was encountered in maintaining temperatures at —65°F over all parts of the tank. General range of the temperatures maintained was —55° to —71°, with at least one thermocouple reading —65° constantly.

The sequence of loading was as follows: 4500 cycles at ambient temperature, 500 cycles at —65°F, 4500 cycles at ambient temperature, 500 cycles at —65°F.

These tests were conducted with excellent fuel sealing performance. No leaks were experienced at any part of the wing structure.

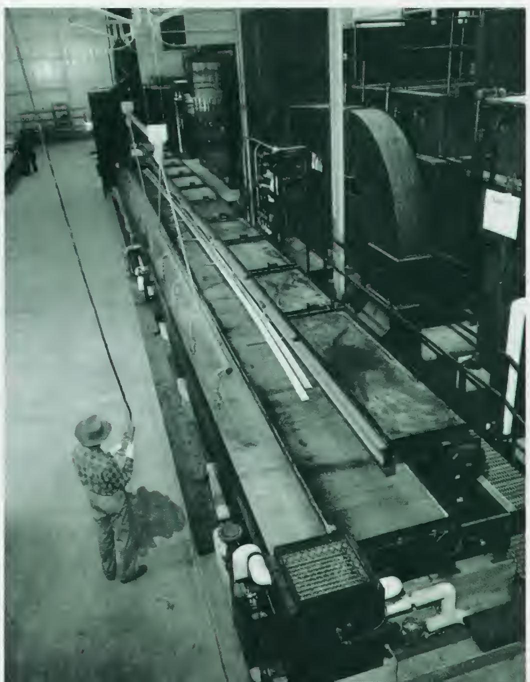
A final air test of 25 psig at ambient temperature still produced no fuel leakage. This program was extremely beneficial in that it was the first full-scale wing vibratory test conducted by Convair. It was also the first time external cooling of fuel was applied with subsequent pumping of the cold fuel through a tank. As a result of trial and error, the first satisfactory rubber tension pad bonding to external skins through the use of Shell chemical Epon 6 was developed.

Parts which have been sealed with a thin coat of Scotch-Weld primer and precured at 150°F are removed from a rack in the spray area.

The process of using soft springs to support the wing in order to get a zero g loading was perfected, permitting realistic plus and minus loads during vibratory tests. One of the most interesting things learned was that non-structural parts, which supposedly were to "go along for the ride," failed first. As a consequence of this vibratory test, critical design factors, especially fatigue on spar lugs, were brought sharply into focus. Later tests utilized this fatigue data to great advantage.

Separate vibratory tests of individual spars confirmed conditions proved by the full-scale wing test. Individual lug fatigue tests using the vibratory beam loading technique permitted extra high loads to be applied rapidly, thus reducing test time and giving realistic values in time to incorporate the data in the initial airplane flight article.

Spar rails are accommodated in a special multi-purpose tank that can accomplish several precuring processes.



The behavior of the wing structure is of critical consideration because the best sealing system will not prevent fuel leakage if structure is failed.

The initial test tank with adhesive sealing has completed more than three years of exposure to salt water atmosphere at San Diego Bay, with no leaks to date. The JP-4 fuel, with red dye, is changed each 60 days with a careful inspection of the tank structure being conducted at each fuel change. The Scotch-Weld seals appear to be in excellent condition. A fourth year of fuel soaking is still in progress, and no change in sealing effectiveness is anticipated.

Fatigue tests of adhesive-bonded joints indicate the bond will outlast the metal structure it binds together. No. F-102A adhesive-bonded wing fuel tank in service has ever leaked.

The Scotch-Weld sealing system employed in construction of the F-102 and F-106 integral fuel tanks is also the logical choice for the Convair 880. Scotch-Weld AF-10 adhesive film combines the properties of good heat aging; good low temperature shear; excellent salt water, humidity, and fuel resistance; and the ability to permit some bond elongation without losing continuity. In addition, the Scotch-Weld metal-to-metal bonding method of assembling aircraft structures provides a bonus in structural strength by distributing loads more evenly over the entire 120-foot wing. This extremely strong wing structure will be both lightweight and fatigue-resistant, and will provide fuel-tight reservoirs for 10,770 gallons of turbine fuel.

Adhesive bonding of integral wing fuel tanks for the Convair 880 is taking place at the recently completed Scotch-Weld facility located at the San Diego plant of Convair. Inside this facility are an electric oven 80 feet long, 20 feet high, and 10 feet wide; six 4 x 10 x 35-foot processing tanks; a paint booth; and a three-compartment pre-curing oven. A craneway structure and exhaust fan system are included in the auxiliary equipment.

Each detail and structural part is cleaned and primed.

The 2,000-square-foot swept wing is then assembled with strips of dry Scotch-Weld tape placed between the faying surfaces of wing skin and structural members. Rivets patterned after the exclusive Convair Straylor rivet are then employed to join the skins, ribs, and spars, at the same time supplying the necessary clamping pressure on the Scotch-Weld tape for the curing process.

Gas-tight corners and lightweight self-sealing dome nuts, developed by Convair, the Nutt-Shel Company, and the Franklin C. Wolfe Company for use with inspection covers, complete the assembly of the wing tank areas.

After final assembling of the wing tank, the entire section is placed in the electric curing oven at a temperature of 325°F. The heat melts the flat Scotch-Weld tape adhesive, and the film then cures to a tough, fuel-resistant barrier between the joined surfaces. The electric oven accommodates two Convair 880 wing-tank sections in one curing operation.

In an area immediately adjoining the Scotch-Weld facility are located the giant wing bucks used in assembly of the "880" wings. Each of these six fixtures weighs 75,000 pounds, and there are three right-hand and three left-hand bucks. Overall length of each is 90 feet; maximum width is 10 feet; and maximum height is 22 feet. These dimensions reportedly make the fixtures the largest and longest ever made for Scotch-Weld assembly.

As in previous Convair aircraft, fuel tank accessibility has been emphasized in the overall wing design. The wing has large removable doors in the lower surface to provide access to system components and to allow inspection of the wing interior. These access doors are of the structural type, and are installed with flush screws and self-sealing, dome-type plate nuts. Structural access doors are designed as part of the basic airframe structure; in other words, they actually carry a part of the wing stress load. The skins of the wing have milled recesses so that the access doors fit flush with the skin.

Fuel tank access doors which are in direct contact with the fuel have molded rubber seals to maintain a fuel-tight fit.

THE CONVAIR 880 FUEL SYSTEM

The Convair 880 carries its fuel in four main integral wing tanks, two to the right and two to the left of the fuselage. The fuel system for each tank is completely separate and independent of the others except for crossfeed lines and valves.

As previously stated, Convair has developed the integral method of construction to the point where fuel leakage is non-existent. With the conventional method, it is necessary to have constant inspection and, eventually, complete stripping and resealing of the wing. Scotch-Weld priming affords excellent corrosion protection, thereby reducing maintenance corrosion problems to a minimum.

All plumbing is installed inside the tanks, thus minimizing the hazard of fuel leakage. Another outstanding feature of the fuel system is that its components are so installed that any one component can be removed without the necessity of draining the fuel.

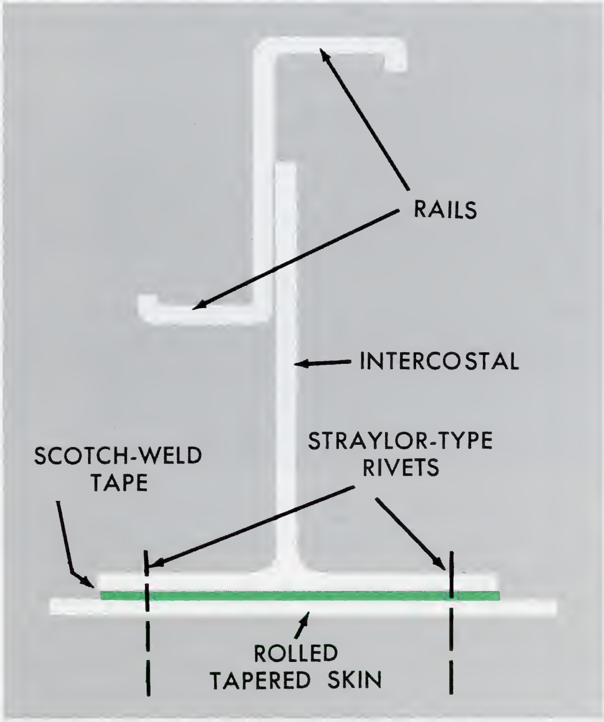
Each main tank is divided into two compartments, a replenishing and a main compartment. Each inboard tank has a capacity of approximately 3,000 gallons, and each outboard tank has a capacity of approximately 2400 gallons. This feature will allow the airline operator to adapt the aircraft to long or short range flight operations.

The fuel system of the Convair 880 consists of five subsystems: 1) refueling subsystem; 2) engine fuel supply subsystem; 3) fuel tank vent subsystem; 4) fuel jettison subsystem; and 5) fuel quantity gaging subsystem.

REFUELING SUBSYSTEM

The airplane is provided with four underwing pressure refueling points, one for each tank. The subsystem has safety features that prevent damage to the wing in case of refueling malfunction. Basically, this subsystem consists of a refueling adapter in line with a double shutoff valve, downstream of which is a pressure regulator that will shut itself off any time the pressure inside the tank rises above the predetermined safety point. An outstanding feature of the shutoff valve is that it has two poppets, one primary and one secondary. Even if one poppet were kept open by foreign matter, the other would stop the flow of fuel into the tank.

A pilot valve with primary and secondary features will automatically shut off the fuel supply when the fuel reaches a predetermined capacity.



Application of Scotch-Weld process to typical rib section of "880" fuel tanks.

On the outboard side of the two inboard pylons, there is a refueling panel which has headset jacks to the intraplane phone service, repeater fuel quantity gages with knobs to preselect any quantity of fuel for any tank, and switches to precheck the primary and secondary system during refueling. A safety feature makes it impossible to replace the panel cover unless all controls are in proper flight condition.

Fueling is completely automatic. The desired fuel quantity is predetermined; then tanks are filled. Fueling is accomplished at a rate of approximately 300 gallons per minute per tank at 50 psig, for a total of 1200 gpm when using all connections simultaneously.

Emergency refueling facilities are provided for each tank by gravity flow at the rate of 150 gpm for each inlet.

ENGINE FUEL SUPPLY SUBSYSTEM

Fuel to each engine is supplied from two a-c electric booster pumps, located in a well inside each main tank. Each booster pump is designed to supply 125 percent of the maximum engine fuel demands. Failure of either unit will not interrupt engine thrust. Operation of either pump is adequate for starting, normal, or emergency operation. Pumps are so located as to operate in any normal flight attitude. The generators (one for each engine) are so connected that a failure of any one generator will not affect fuel system operation.

A crossfeed system permits supply of one or all four engines from any one or any group of tanks. The selection is controlled by electrically-driven fuel shutoff valves installed on the rear spar.

There are two transfer pumps in each outboard tank and one in each inboard tank. These pumps maintain the booster pump wells full of fuel at all times. Booster and transfer pumps are each provided with a low-pressure switch connected to a light, installed on the flight engineer's panel. This light goes on, if there is a pump failure. Each booster pump is provided with flappers, to permit gravity flow into the well. Each transfer pump and its control relay has the same power source.

An engine-driven fuel pump and self-bleeding mass flow meter transmitter are installed for each engine. Warning devices in the pilot's compartment indicate fuel pressure drop for each engine-driven fuel pump and for each booster pump.

VENT SUBSYSTEM

Each compartment is provided with float type vent valves. The outlet for the vents is located outboard, near each wing tip. Tests show that ice will not form on the flush scoop configuration of these outlets.

The vent valves are normally open, but fuel will close them off. However, the vent valves located at the high portion of each main tank are provided with a safety relief valve to permit venting, even though the vent valve is kept closed by the fuel. The vent subsystem maintains an internal differential presssure in the tank of +3.0 psi to —2.0 psi, when descending from 40,000 feet at maximum speed with tanks 20 percent full, or when in maximum climb with 130°F fuel temperature.

JETTISON SUBSYSTEM

Realizing the fire hazard during dumping, Convair has discarded the gravity dumping system in favor of a pressurized system. Hydraulically-driven fuel pumps are located in each main tank. The pump inlet consists of a stand pipe with the inlet located so as to trap the amount of fuel required by CAA regulation. In addition, a jettison scavenge fuel pump with inlet is located at the lowest point in each inboard tank to facilitate a complete jettison of fuel, in event of a foreseen crash landing. Rate of discharge of each pump is 80 gpm at 18 to 20 psi pressure. The hydraulic pumps which operate the fuel jettison pumps are connected to the primary and secondary hydraulic systems. The discharge point of the jettison system is located near each wing tip. As indicated by wind tunnel tests, this will preclude possibility of fuel discharge into the engine jet stream. A shut-

off valve actuated by jettison pump pressure is located near the jettison nozzle to prevent overboard siphoning of fuel and to serve as a flame arrestor.

An excellent feature of the "880" fuel jettison subsystem is that it can be periodically checked out. To check the subsystem, the hose of the fueling truck may be connected to the jettison outlet tube, and the hydraulic fuel dump pump will then dump fuel from the system tank to the truck tank.

This jettison system is considered to be lighter, as well as safer, than the conventional chute dumping system.

FUEL QUANTITY GAGING SUBSYSTEM

A null balancing, transistorized fuel quantity gaging system is provided. Gages are equipped with compensators to correct for the various fuels which will be used in this airplane. Use of plugs and receptacles ensures that the gages may be installed or replaced without special tools. As previously mentioned, repeater fuel indicators, with the same accuracy as the gage at the flight station, are located at the underwing refueling points for ground reference.

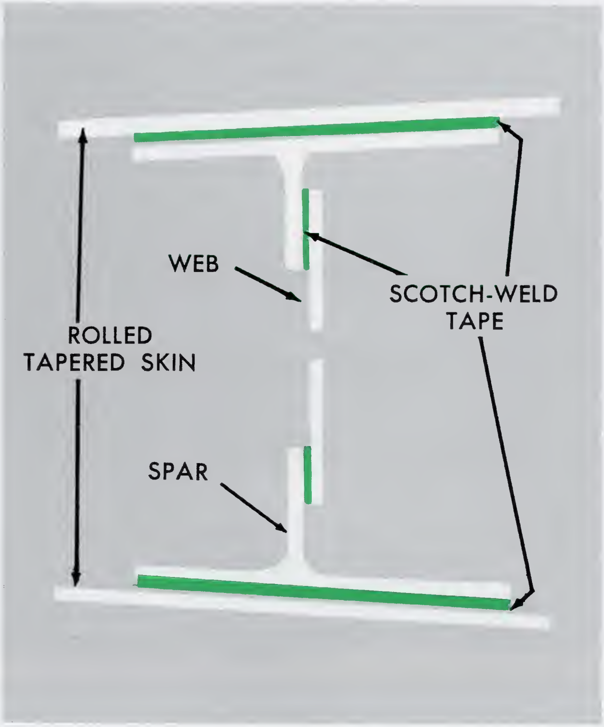
A totalizing measurement system is provided for every tank, so as to gage each main tank, each replenishing tank, or the total of all tanks. Measurement is on the basis of weight, rather than volume.

To determine the location for fuel probes, Convair built a scale mockup of the wing. This scale mockup is made of plastic and contains all the wing structure and fuel system components and plumbing. By taking the intersection of fuel levels at different attitudes, it is more realistic and easier for the fuel gage manufacturer to determine the probe location. In addition, this scale mockup has helped in determining the location of the fuel system components.

GENERAL SYSTEM REFINEMENTS

Supporting the major features of this new fuel system are a multitude of details designed to make the system function smoothly and efficiently under all conditions.

Pressure refueling fittings may be used for suction defueling, with proper ground equipment, at the rate of 50 gpm. All d-c operated valves for line shutoff, crossfeed, and emergency operation, have visual indicators. It is also possible to operate the valves manually for test purposes with the electric motor section removed. Crossfeed valves, located in the crossfeed manifold, are controlled from the Flight Engineer's panel, and may be removed from the line without fuel leakage.



Application of Scotch-Weld process to typical spar section of "880" fuel tanks.

An emergency shutoff valve for each engine fuel supply system, mounted above and adjacent to the firewall, is controlled from the fire control panel. When the emergency shutoff valves are fully closed, an indicator light on the fire control panel lights up "ON."

Line shutoff valves on each of the four tanks are electrically operated by controls on a panel in the pilot's compartment. A warning light indicates any malfunction of the valve. The line shutoff motors are replaceable without removing the valve from the line and without fuel leakage.

In keeping with Convair maintainability, all fuel system components are easily removable without draining any of the tanks; even the primary seal portion of the tank sump drain valve is removable without leakage.

The design features of the Convair 880 fuel system were laid down with the definite purpose of helping to carry out the objective of the airplane itself — to be the fastest, safest, most economical commercial jet transport in the world. This meant creating a lightweight, high capacity, and efficient fuel system that stresses both reliability and maintainability.

Such a system, combined with use of the Scotch-Weld process for the first time in the production of commercial aircraft, adds significant support to achievement of the "880" objective.

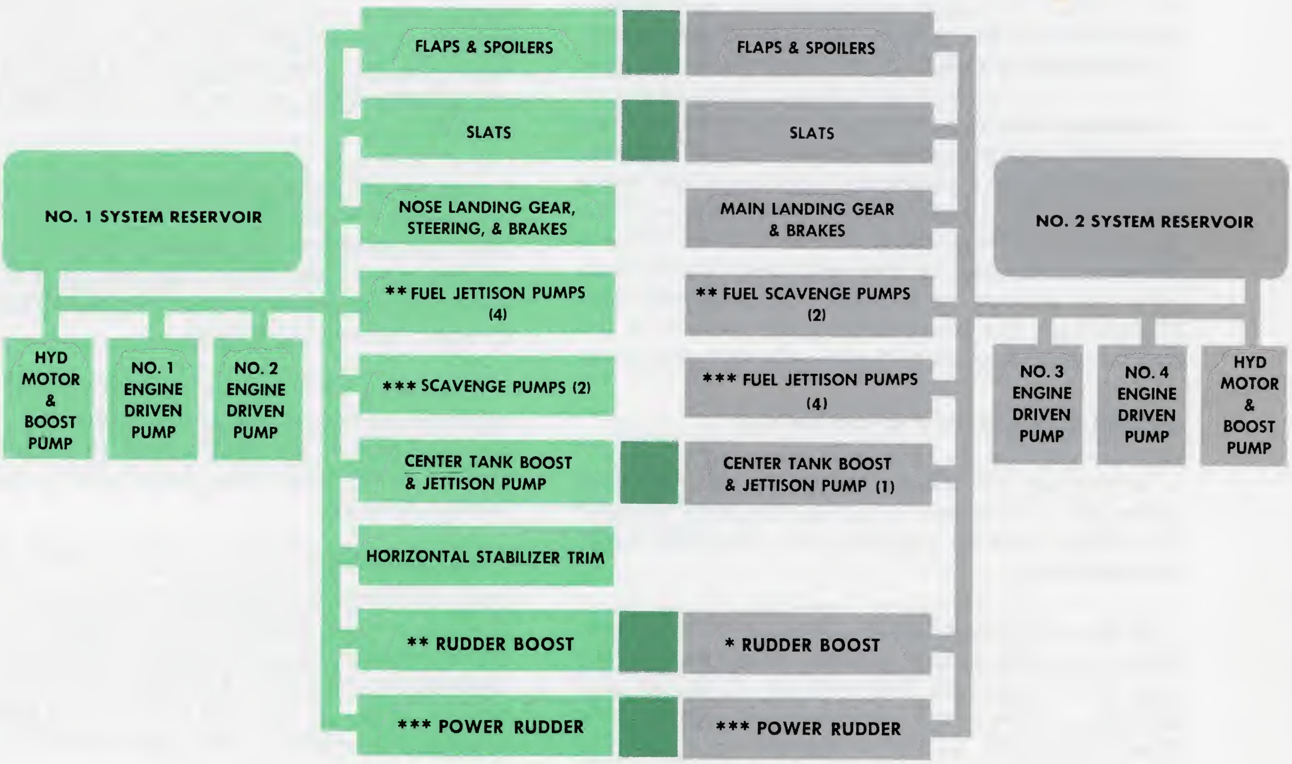
Hydraulic Systems Convair 880 and 990

There are major differences between hydraulic systems of the new Convair jet airliners and those of Convair-Liner type aircraft. Where a Convair 440 has one main system and an auxiliary pump, the "880" and "990" have two complete, independent systems, with an auxiliary pump for ground operations.

A second difference is in relative sophistication of hydraulics in the jet transports. In most piston-engine aircraft, the main hydraulic system is used only intermittently, principally during takeoff and landing. In the "880," hydraulic power is used more or less constantly during flight for servo operation of the spoilers and stabilizer trim. Hydraulic motors defuel the tanks, airborne or on the ground, and, in the "990," hydraulic actuators supply rudder boost. Demands are not only extensive but the systems require the utmost in efficiency and reliability.

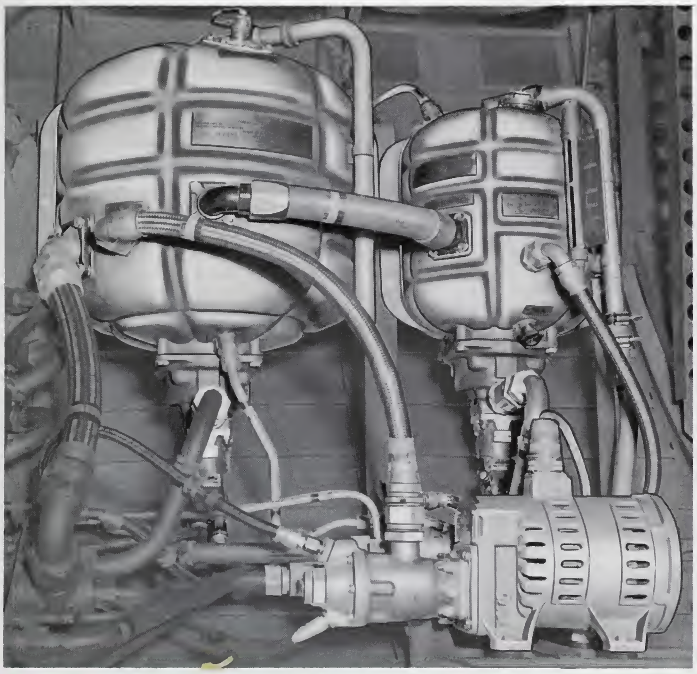
In the Convair jet transports, both No. 1 and No. 2 systems are 3000-psi, closed-center systems, each powered by two engine-mounted pumps. Both systems operate flaps and spoilers, and also the slats on the larger gross-weight versions. The No. 1 system operates the nose landing gear, including steering and brakes, and horizontal stabilizer trim. The No. 2

Two independent systems meet new standards of performance and reliability in Convair's new jet airliners

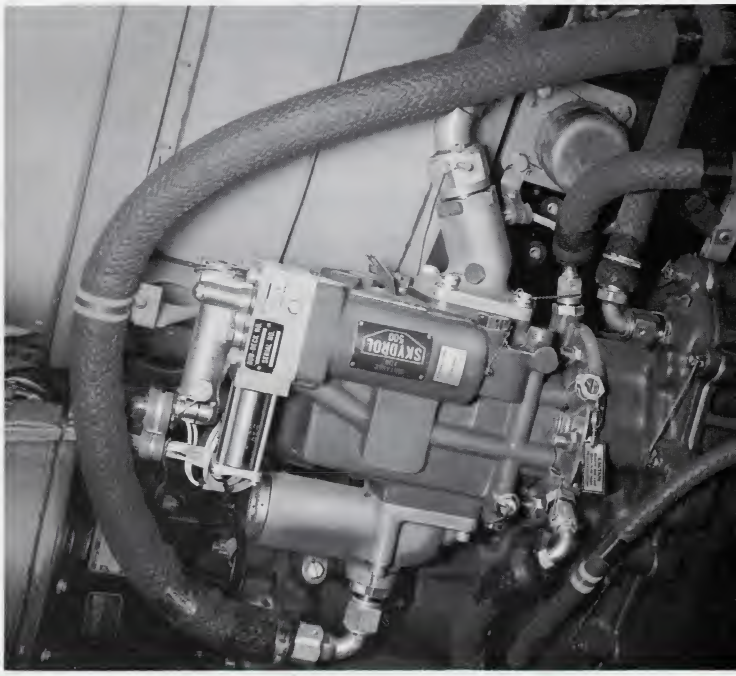


* SOME 880M VERSIONS   ** ALL 880M VERSIONS   *** 990 ONLY

Hydraulic System Block Diagram
880M–990



View from 880M compartment door shows No. 2 and No. 1 reservoirs (left and right respectively), supply pumps (below reservoirs), auxiliary pump.



One main hydraulic pump is mounted on each engine on forward face of forward (transfer) accessory drive gearbox, just left of the starter.

system operates main landing gear and brakes. Operation of fuel jettison and scavenge pumps is divided between No. 1 and No. 2 systems. The auxiliary pump supplies power to operate either of the main systems. For emergency main gear door extension and braking, large-capacity accumulators and an airflask provide high-pressure air storage.

Hydraulic fluid is Skydrol 500A, a fire-resistant phosphate-ester chemical, currently considered the best of the hydraulic fluids available. Since it dissolves or softens many sealants and finishes, aircraft using Skydrol must be designed for it. Interior pod-pylon finish, for example, is Skydrol-proof as is the Scotch-Weld prime coat and the Scotch-Weld in the wing. Some hydraulic hoses are Teflon-lined, and all valve and actuator components are of materials unaffected by Skydrol.

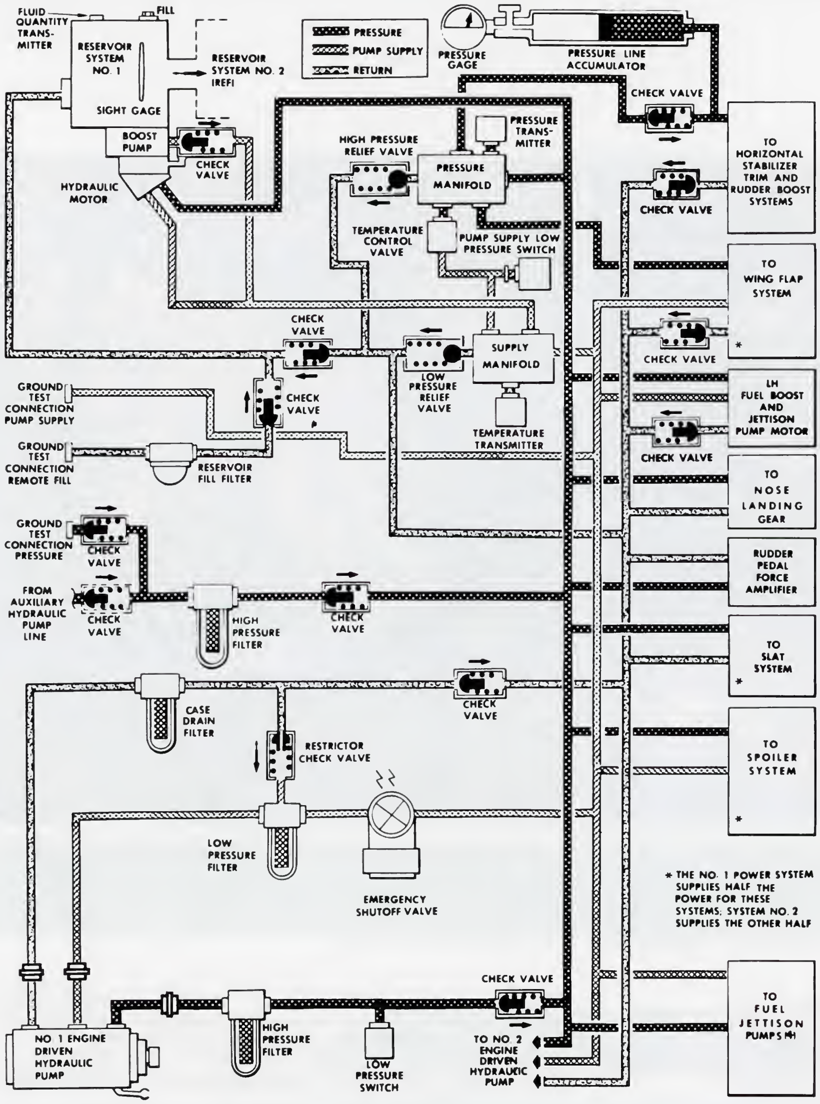
Reservoirs and ground connections are located in a compartment aft of the main wheel wells. The reservoirs are interconnected, so that they can be filled simultaneously from one point. The No. 1 system reservoir has a gravity filler neck and a remote pressure fill connection. Interconnect line fittings are located at a level so that a leak in one system will not cause depletion of the fluid in the other.

Pressure and supply line connections for ground test and operation, and the reservoir filler connection are just forward of the hydraulic compartment access door. A sight gage on No. 1 reservoir is marked "FULL, SYS DEPRESS'D; REFILL, SYS DEPRESS'D; FULL, SYS CHG; REFILL, SYS CHG. Fluid quantities can also be read on the flight engineer's panel. The No. 1 reservoir holds approximately 2½ gallons, the No. 2 reservoir approximately 8½ gallons.

Each reservoir is vented to the compartment, which is maintained at cabin pressure. The low surface pressure is a factor in preventing air entrapment. At each reservoir outlet is a variable-delivery vane-type boost pump, operated "bootstrap" fashion by hydraulic motors powered by the 3000-psi system. The pumps maintain a normal pressure of 70 to 80 psi in the supply lines to the engine-mounted pumps.

At each pylon, the engine supply line is routed through a firewall shutoff valve and a filter. The shutoff valve is operated by a d-c motor, controlled from the flight compartment by switches on the flight engineer's panel.

One main hydraulic pump is mounted on each engine on the forward accessory drive gear box. No. 1 system pumps are on the two left-hand engines, No. 2 pumps on the right-hand engines. The pumps are piston variable-displacement type. That in the "880" (the "990" pump is larger) has a flow capacity of 6 gpm at 1500 rpm and 16 gpm at 3750 rpm. A shear section in the pump protects against major damage from a malfunction that might cause a sharp rise in system pressure.



Hydraulic System No. 1 (Typical)

From the pump, fluid flows through a high-pressure filter in the pylon. The low-pressure and high-pressure filters are mounted close together, with access openings to allow quick inspection. These filters (on the "880" only), as well as the auxiliary system filter in the hydraulics compartment, have a red pop-up button. When pressure across the filter drops more than a specified amount, the button projects until the red is visible, and remains out until manually depressed. It is thus possible to tell at a glance when a filter needs servicing.

Each system high-pressure line returns to an accumulator in the hydraulic compartment. This is precharged with dry air or nitrogen to a pressure usually ¼ to ⅓ of system pressure; it serves as a reserve supply of fluid for sudden system demands, and also for dampening pressure surges.

Both high- and low-pressure lines have pressure relief valves to dump excessive pressure to return lines. In the "880," in the low-pressure line to each engine, is a restrictor-check valve. The restrictor allows a constant flow of 1 gpm from the filter to the unpressurized return line and serves to remove any accumulation of entrapped air in the filter. The check valve serves several purposes. It is an alternate filter bypass to ensure a supply of hydraulic fluid to the pump. Because the pump case drain line is routed by this valve, it allows circulation through the pump when the firewall shutoff valve is closed. Also, it eliminates pump knocking caused by excessive pressure differential during engine start or slow speed operation.

In each 880 system high-pressure line is a solenoid-operated temperature control valve. This can be opened by the flight engineer to raise fluid temperature by recirculating from high-pressure line to pump supply line. The valve is not normally used unless fluid temperature falls below 0°C. Radiation and convection from the airplane's 300 feet of lines keep fluid temperature well below system limitations.

The auxiliary pump is a variable-displacement pump, driven by a three-phase 115/200-volt motor. It draws fluid from the larger No. 2 reservoir through a suction port located at approximately the reservoir interconnect line level, so that it will not empty the No. 2 reservoir in the event of a leak in the No. 1 system. Output is to both No. 1 and No. 2 pressure lines through high-pressure filters. The ground pressure line utilizes the same filter. A check valve is installed upstream from the auxiliary pump line con-

nection to prevent motoring of the pump from the ground cart. Another check valve is installed downstream from the filter, to shut off main pump pressure from the auxiliary system.

On the ground, the auxiliary pump can provide hydraulic pressure for operating system components. It must be on to prime the engine pumps prior to engine start and may be used to check out the controls and to pressurize the accumulators.

HYDRAULIC OPERATION OF FLIGHT CONTROLS

Each of the three spoiler sections in each wing (one inboard and two outboard) is raised by a pair of piston actuators, one for each hydraulic system. Two dual servo valves in each wing, one for inboard and one for outboard spoilers are operated by pushpull linkage from the aileron-spoiler mixer at the airplane centerline. A followup mechanism stops servo valve flow when the spoilers reach the position set by the pushpull linkage. On one hydraulic system, spoiler hinge moment is reduced but actuating speed is the same.

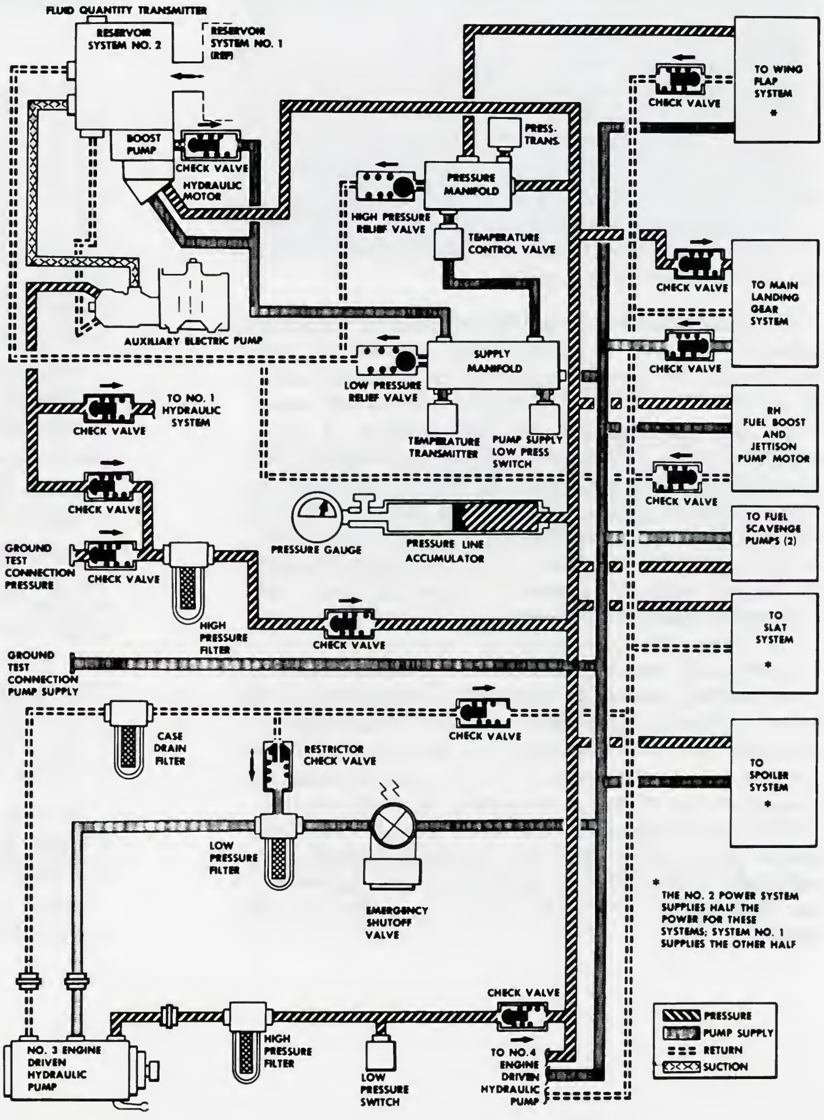
If aerodynamic pressures are too strong, hydraulic pressure can leak back through the servo valve permitting some blowdown. Further blowdown causes the followup linkages to open the servo valve, and the extra hydraulic pressure generated by the air loads will be relieved.

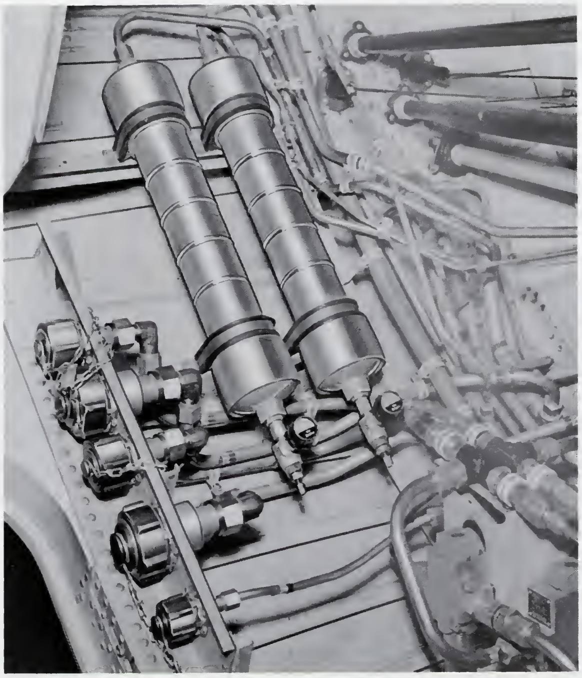
Flaps are actuated by recirculating ballbearing screwjacks, driven by high-speed torque tubes from a gearbox at the airplane centerline. The gears are planetary type and are driven by two hydraulic motors, one for each hydraulic system.

The flap motors are governed by a selector valve, controlled by cable linkage directly to the flight compartment. To prevent asymmetric flap extension, flow to the hydraulic motors can be cut off by an electrically-actuated dual shutoff valve, controlled by rotary switches at the outboard ends of the torque tube. If the switches are out of phase from asymmetric rotation of the torque tubes, power is cut off from the flap motors.

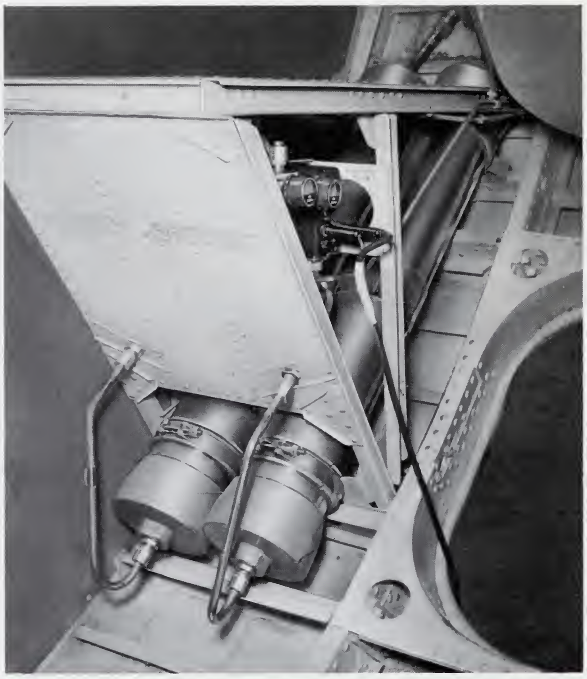
The leading edge of the "880" horizontal stabilizer is moved up and down by a traveling nut on a screwjack. The nut is turned by a worm gear driven by a hydraulic motor. Power is metered by a selector valve mounted on a followup screw. Followup screw rotation is controlled by cables to the flight compartment trim wheel. The stabilizer mechanism of the "990" aircraft is of a different design.

Hydraulic System No. 2 (Typical)





System accumulators and ground test panel are forward of access door. Four connections are for pressure and supply lines; lower is filler line.



Pair of accumulators, aft of access door, are for main landing gear operation. A cylinder is not required for the anti-skid brake system.

LANDING GEAR

Nose and main landing gears, being in two different hydraulic systems, are linked together only in the flight compartment control linkages. The landing gear control lever has three positions, UP, NEUTRAL, and DOWN. NEUTRAL is the normal flight position and cuts off all power to both gears.

The nose gear is retracted and extended by a piston actuator; the door is mechanically operated by gear movement. The gear is locked up by hydraulic action of an uplatch cylinder, tripped by mechanical means when the gear reaches the up position. A door sequence valve, in turn mechanically operated by the gear uplatch cylinder, locks the doors up when the gear is latched. Moving the selector valve to DOWN position, ports pressure through a priority valve, first to the *door* uplatch cylinder to release the door; then, to the *gear* uplatch cylinder to release the gear; and to the gear actuator to lower the door and gear.

Nose wheel steering, controlled by cables from the nose steering wheel in the flight compartment, is powered from the gear-down line, and hence is operative only when the landing gear lever is in DOWN position. A steering control valve ports pressure to dual actuating cylinders, the pistons of which are connected by a rack gear. The rack moves a segment pinion gear that is part of a steering torque arm assembly. When the pilot releases the steering wheel, the nose wheel is free to caster, regardless of its position.

The main gear hydraulic system, including brake lines, is isolated by a check valve in the pressure line. Downstream of this MLG check valve are two accumulators, joined by tubing, to assist the pumps in making up the pressure drop caused by gear retraction. A priority valve between pressure line and accumulators restricts flow to the accumulators when landing gear system demand is greatest, and opens to permit flow from the accumulators when line pressure drops beyond a certain point.

The MLG selector valve contains spools for both normal and emergency operation. Normal actuation is through two sequence valves, one for each gear and one for each door. With gear up and door closed, and the gear handle in NEUTRAL, all gear and door *up* and *down* lines are vented to return.

Door sequence valves are mechanically positioned by gear uplatch and downlatch cylinders; *gear* sequence valves are positioned by door movement. When the control handle is moved to DOWN, the door sequence valve ports pressure to lower the doors. Door movement actuates the MLG sequence valve to unlatch the gear uplatch and to lower the gear. The gear downlatch mechanically positions the door sequence valve to raise the doors again.

Moving the landing gear control handle to UP, essentially reverses the process to retract the gears by porting fluid through gear-up lines.

Emergency extension is by a combination of pneumatic and mechanical means. MLG accumulator air

pressure opens the doors. The emergency gear-down handle, in its first third of travel, positions the emergency spool in the selector valve to block hydraulic pressure and vent the lines to return, and at the same time opens an air valve to admit air to shuttle valves on the door actuating cylinders. The shuttle valves prevent air backing up in the hydraulic lines; air pressure drives the cylinder piston to unlatch and open the doors, and holds them open by air pressure. The second third of travel of the emergency lever mechanically unlocks the door latches, in the event of failure of the pneumatic system to operate, and the last third of travel mechanically unlocks the main and nose gear uplatches, allowing the gears to "free fall."

In "880" aircraft (but not in the "990") a landing gear speedbrake handle is provided, to lower main gears only for deceleration. Hydraulic operation is the same as that controlled by the landing gear handle, except that the speedbrake handle operates cable controls for only the MLG selector valve and not for the nose gear. The speedbrake handle will not lower the main gear unless the landing gear handle is in NEUTRAL position.

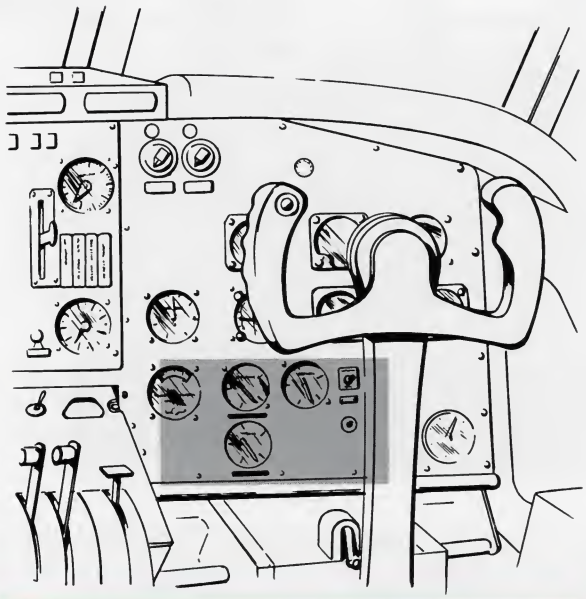
Brakes are normally operated by pilot toe pressure on the rudder pedals. Movement is transmitted to metering valves, one each for the nose gear and main gear. Metered flow is to a brake adjuster that isolates the pressure line from the brake actuators. The actuators are small interconnected cylinders (at each wheel) that compress the disc stack.

The brakes are controlled by the Hytrol antiskid system, by means of detectors, electrical control circuitry and valves, and a pressure modulating accumulator. A flywheel inertia mechanism at each wheel senses incipient wheel deceleration and cuts off hydraulic pressure to that wheel brake before the wheel locks, reapplying pressure when the wheel accelerates. The accumulator, which is ahead of the metering valve, has a restricted inlet that progressively lowers brake pressure when brake reapplications come in rapid succession. This provides only the required safe brake pressure for the rolling speed at the moment of application, and results in smooth, even deceleration.

A 300-cubic-inch air flask, charged to 3000 psi, is carried adjacent to the nose wheel well for emergency operation of the main wheel brakes. Pilot control is by a spring-loaded lever on the engine instrument panel. The knob operates an air metering valve. Air pressure is admitted to the brake actuators via a shuttle valve.

Emergency operation overrides both the hydraulic and Hytrol systems. The air flask supplies approximately nine full brake applications at the main gears — more, if the pressure is not fully vented between applications.

A parking brake handle on the instrument panel is essentially a detent on the brake actuating linkage, and functions only to hold the brake metering valves open. Main landing gear brake accumulators hold



Gages on left, on copilot's instrument panel, indicate No. 1 and No. 2 system pressures. Third gage shows hydraulic brake pressure available.

brake pressure for several hours after engine shutdown.

INSTRUMENTATION

Main pressure gages for the two hydraulic systems, and the MLG brake pressure gage, are on the lower portion of the copilot's instrument panel. Most of the remainder of the instrumentation and the controls are on a subpanel at the upper left corner of the flight engineer's instrument panel.

At the top of this subpanel are warning lights for low pressure in each pump pressure line, with the firewall shutoff valve switches just below. The firewall valves would also be closed if the fire control handles, above the engine instrument panel, were to be pulled. There is one supply line low-pressure warning light for each system.

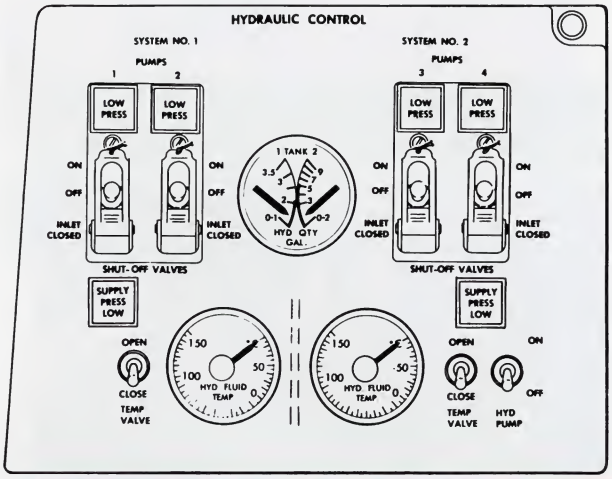
A dual-indicating fluid quantity indicator centered in this panel is operated by transmitters in the reservoirs. There is a temperature indicator for each system; transmitters are in the low-pressure pump supply lines in the hydraulic compartment. Adjacent to each

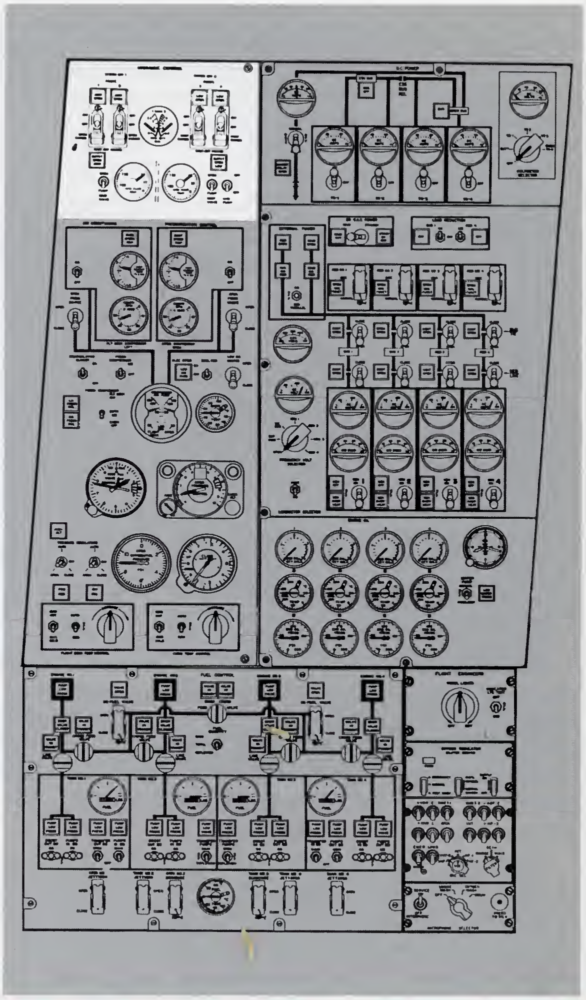
temperature indicator is the control switch that opens the temperature control valves.

The auxiliary pump switch is at the lower corner of the panel.

The MLG brake pressure gage, on the copilot's panel, indicates pressure downstream from the check valve which isolates the main gear and brake system. Adjacent to the emergency brake knob is a bottle pressure indicator. A second gage downstream from the air metering valve shows actual pressure being applied to the brakes.

The emergency brake flask, the two MLG system accumulators, and the pressure line accumulators for both hydraulic systems are equipped with pressure gages for servicing.





Subpanel (left) at upper corner of flight engineer's panel (right) contains fluid quantity and temperature indicators for each system, and firewall cutoff, auxiliary pump, and temperature control switches.

HYDRAULIC COMPONENTS FOR LONG-RANGE "880/990"

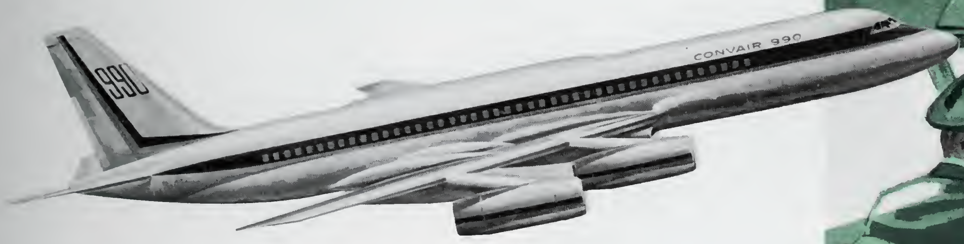
The description of the hydraulic systems thus far is applicable to all versions of the Convair 880 and 990 aircraft, except as noted. Differences exist in some areas because of the variance in controls, wings, and fuel systems.

The standard medium-range "880" has four fuel jettison pumps, one in each tank, mounted on the wing rear spar. Two scavenge pumps are provided for emptying inboard tanks. Jettison pumps are operated by the No. 1 system—scavenge pumps by the No. 2 system.

The long-range "880" and the "990" have center section fuel cells requiring, in addition, two combination boost and jettison pumps, one pump for each hydraulic system. The No. 1 system powers both wing scavenge pumps and the outboard left-hand jettison pump; the No. 2 system powers the other three jettison pumps. This division of pump power sources is to insure that emergency jettisoning of fuel by one hydraulic system, in the event of failure of the other system, will not cause airplane CG to move too far forward.

Both of these larger gross weight aircraft have leading edge slats, operated by both No. 1 and No. 2 systems. Operation is similar to that of the flaps, a central gearbox rotating torque tubes that actuate screwjacks to extend the slats. The selector valve is controlled by the same cables that operate flap selector valves.

In the "880M" airplane, the No. 1 system provides power operation of the rudder in certain low-speed situations, when the flight tab does not furnish sufficient surface deflection. At approximately 15° or more deflection of the tab, a hydraulic actuator moves the rudder directly.



FURNISHINGS

CONVAIR 880M/990

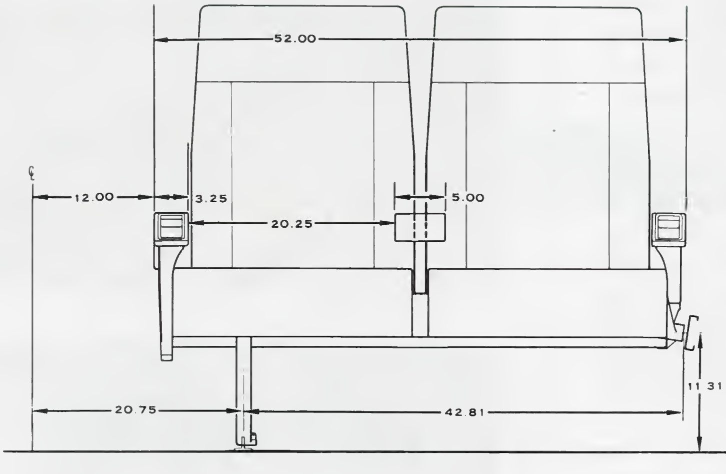
When a passenger first steps into one of the Convair jet airliners, his first impression, particularly if he is a seasoned traveler, will probably be of spaciousness — space to walk in, elbow-room, enough room to stretch out a little and relax.

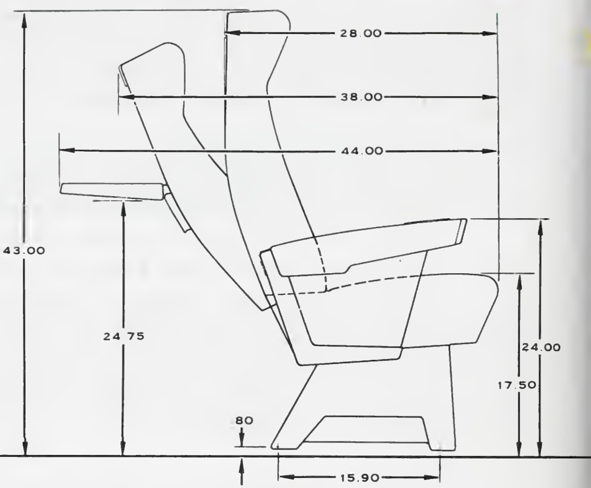
It is no trick of decor. In the four-abreast seating of the Convair jet airliners the passenger probably has the most move-about room ever designed into a standard transport. Aisles are a full two feet wide; seats are as wide between armrests as the ordinary parlor chair. The ceiling is more than seven feet above the aisles.

The "tunnel effect" — the perspective of the long row of seats exaggerated by the arched cabin shape — is effectively diminished by several decorative devices. In every 20 feet of ceiling, a five-foot length is dropped approximately three inches. Upholstery colors are varied between blocks of seats to accentuate the compartmentalization effect. The continuity of the line of hat racks is broken by stowage bins placed at intervals, each bin provided with a door.

Standard first-class 88-passenger seating arrangement, for example, has 19 four-abreast rows and a 12-place lounge forward. This can be converted to five-abreast seating in almost any desired combination of first-class and coach arrangements, with or without lounge, up to a maximum passenger capacity of 110.

Passenger Seating





Convair is no newcomer to the art of seating passengers. In almost 15 years of producing such famous airliners as the "240," "340," and "440," Convair has acquired a vast store of knowledge and experience in the comfort and safety of passengers.

Beginning with the "240" passenger seats, Convair has pioneered the use of ductile sheet metal construction as a safety measure against impact. For this built-in safety feature, Convair received recognition from the Aviation Crash Injury Research (AvCIR) of Cornell University.

Custom-designed "880/990" seats are classic examples of safe, functional design. As an extra margin of safety, the seat attachment fittings are "built into" the extra strong fuselage and floor structure.

In the first class arrangement, the "880" and "990" have four-across seating in the passenger cabins, two on each side of a 24-inch central aisle. Each seat has a 20¼-inch seating space between the armrests. The center armrest, which is 5 inches wide, can be removed to provide a clear area, if desired. The normal distance between the rows of seats is 38 inches. Because of the

unique Convair seat design, providing the greatest shin room in the industry, a six-foot man can stretch his legs to their full length. At this seat spacing, the seatback can be tilted from the vertical in varying degrees to a reclining position of 38 degrees. A touch of the finger swings out integral trays from the seatback just ahead. The trays are available for dining, cocktails, or for use as desks.

In the coach configuration, there is five-across seating with rows of two seats on one side of the aisle and rows of three seats on the other. The coach seats are only two inches narrower between armrests than are those on the first class version. It is interesting to note that the coach seats on the "880" and "990" are the same size as the first class "440" seats. Constructionwise, the coach seats are the same as the first class seats and embody all of the safety features.

The Convair 990 passenger seats will be attached to tracks running fore and aft, the length of the passenger cabin. The seats will be adjustable in increments of one inch. This feature, which adds greatly to the versatility of the aircraft, will hold conversion time to a minimum.

The passenger seats on the Convair 880/990 are by far the lightest commercial jet aircraft seats in the industry — and the safest. Employing the Convair-proved concept of formed sheet metal construction, the seats are designed to collapse in failing rather than to break apart. A "breaking" tubular structure (as used in most conventional seats) becomes a bed of lethal spears, and greatly increases the hazards of emergency conditions. On the other hand, ductile sheet metal construction progressively collapses and, while doing so, acts as a very efficient energy absorber.

The standard footrest is made up of a pair of aluminum tubes, one padded, simply contrived for use or for swinging out of the way. Remainder of the space under the seat, a minimum of 10 inches high, is available for stowing packages.

The back of the seat holds a food tray, stowed by swinging it up into the back and latching. Unlatched, the tray and support arms swing back, and the tray folds down to level position. Since the tray has a flat surface, it is equally well adapted for use as a writing desk. Trays can be attached to lounge and front row seats by special attachments.

Ashtrays are in outboard and inboard armrests. Reading lights, call buttons, and air and oxygen outlets are all overhead. The reading light is a soft-focus lamp adjustable within the necessary range. Fresh air outlets are standard ball type. An inconspicuous panel covers the oxygen masks, more fully described later herein.

The importance of energy absorption has become paramount in passenger safety. Convair has developed an energy absorber that works in conjunction with passenger seat belts. The unit, fastened to each safety belt between the strap and the seat base structure, moves when a force of 700 to 800 pounds is exerted on it. To survive high-impact landings, the passengers must be held in their seats, and the seats must remain attached to the aircraft. It was learned that, by the use of energy absorption, it is possible to limit peak decelerations of passengers by decelerating them over a slightly longer period of time. The load transmitted to the seats remains below the seat failure point until the energy absorber travel is exhausted.

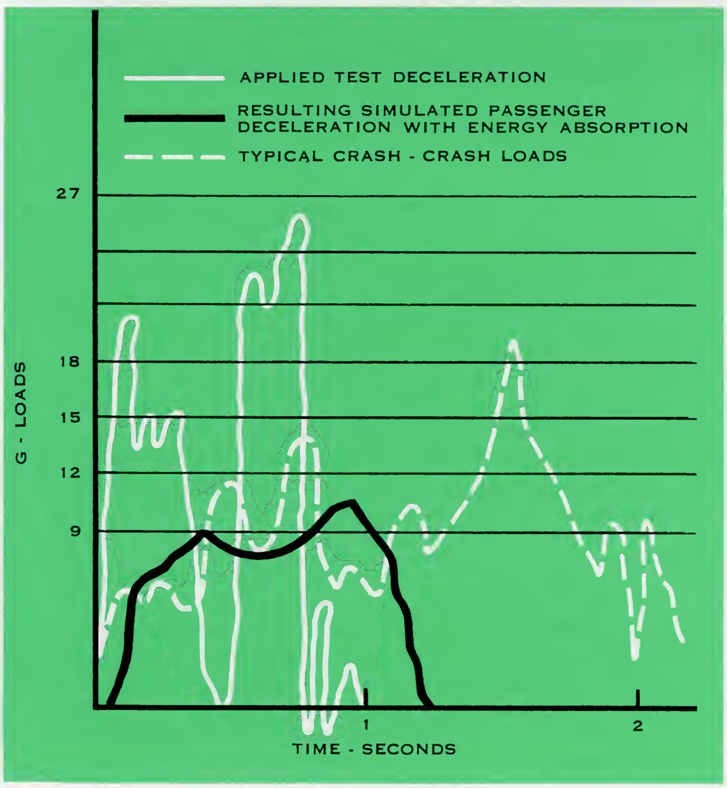
Among the many tests that were performed on the Convair 880/990 passenger seating, the dynamic tests proved of special interest.

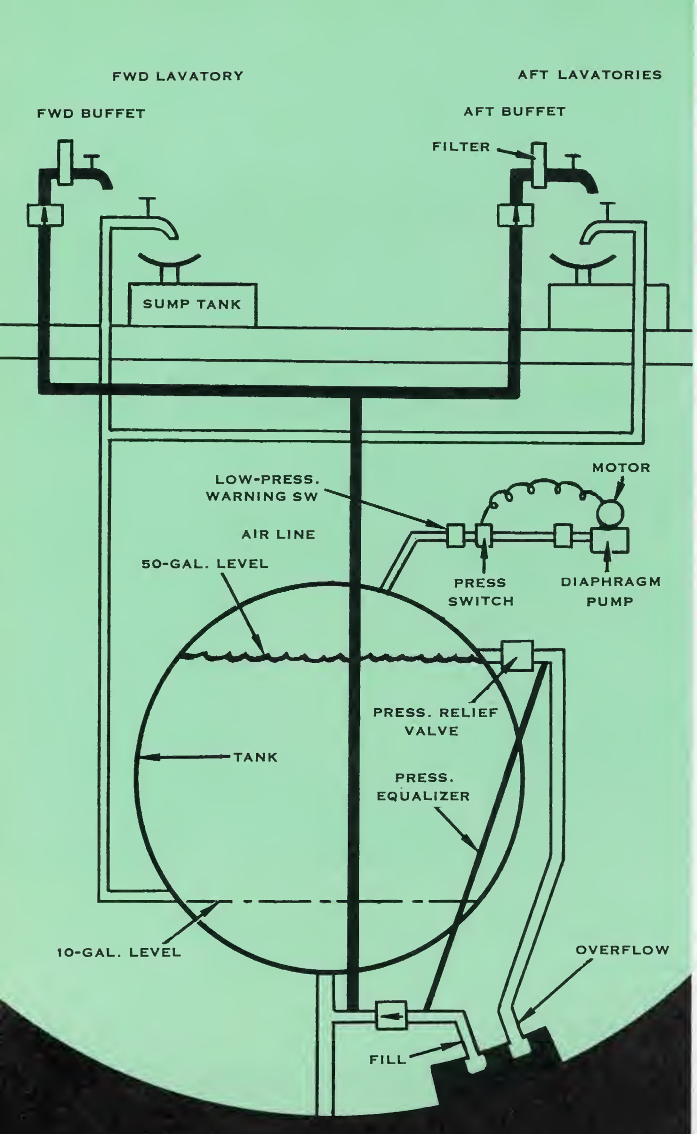
To simulate high-impact landings, the dynamic tests were set up with production-type seats containing 170-pound articulating dummies. The test unit took the form of a giant swing that was released from varying heights. In each test, the swing was stopped abruptly with restraining straps; the forward deceleration and associated data were recorded on magnetic tape.

Tests, with and without energy absorbers attached to the seat belts, were conducted under varying g-loadings. Without the energy absorbers, the seats collapsed; with the energy absorbers the seats stayed erect — the energy absorbers taking the initial impact. In no case did the seats break loose.

The legal requirement for an airplane passenger seat is that it withstand a forward force of 9 g's. Preliminary tests have proved that the Convair-developed seats for the "880" and "990" will not break loose, even when subjected to a force of approximately 15 g's.

PASSENGER SEAT ENERGY LOADS





WATER SYSTEM—SCHEMATIC

CABIN INTERIOR

The fuselage structure is essentially a double-wall tube, of which the upper half (a little more than half, actually) is the cabin. The inside of the thick outer skin, aft of the wing, is covered with sound-damping acoustical tape, in multiple layers as necessary. Insulating Fiberglas blankets several inches thick fill the space between inner trim and outer skins. The stretched-Plexiglas windows are double-paned, with an insulating air space between, and a second air space between inner and outer windows.

The cabin is thus completely surrounded by soundproofing and partially sound-isolated with tape. The second line of defense against noise is the floating shell treatment of interior trim and floor, accomplished by shock-mounting all panels and components of the cabin interior. Floor, wall, and ceiling panels are all designed to keep out or absorb external and internal noise by means of sound barriers, sound absorption, or a combination of both.

Wainscot panels are sandwiches of Spongex polyvinyl chloride foam between Fiberglas, bracketed to beltframes and mounted on rubber grommets. Under the wool carpeting is a polyurethane foam pad. The canopy above the hatrack is Fiberglas.

General cabin illumination is indirect, by fluorescent lamps alongside the ceiling, concealed from view by the inboard edge of the canopies above the hatrack. Aisle lights illuminate the width of the aisle only. All lamps, and the reading-lamp sockets, are replaceable without removing finish covering or using special tools.

Two passenger coat compartments are regularly provided, one forward and one aft, although some airlines have added others. Additional coat closets may be used as class dividers, by removing a row of seats. The closets may be attached at rows 4, 6, 8, 10, and 12 (numbering the rows as in first-class lounge configuration). A coat closet on each side may serve to divide the cabin into two, or even three, sections.

A magazine rack is located forward and another aft. At each seat, a pocket for books or magazines is attached just below the food tray in the seat back.

WATER SYSTEM AND LAVATORIES

The water system is centralized, one tank supplying potable water for all purposes. The tank is serviced through an external access door and may be filled at a rate of 10 gpm. Pressurization is by diaphragm air pump, rated for continuous duty operation, with an air space to act as a pressure reservoir. Water is piped to forward and aft buffet coffee-making and drinking water outlets, and to the three lavatories, one of which is forward and two aft. There are four lavatories in the "990."

Standard airline lavatory appointments are provided — mirror, call button, electric razor outlets, stowage cabinets, and dispensers for towels, soap, etc. Toilets have standard airline connections for ground flushing and charging without entering the lavatory compartment. Illuminated OCCUPIED-VACANT signs, visible to the passengers, are installed at each lavatory. The door lock also displays an OCCUPIED sign when the door is locked.

BUFFETS

Design, size and number of buffets varies with each airline. Two are usually installed forward and one or two aft. They are carefully designed to provide maximum utility in minimum space.

Hot water may be provided by electric heating elements, or cold water by dry ice refrigeration. Storage space is provided for food or food trays, or for beverage containers, liquor, glassware, or whatever the individual airline may desire. Cooking and/or roll-warming ovens are usually provided.

STEWARDESS FACILITIES

Attendants' seats are usually mounted on the bulkheads forward of the entrances, facing aft, or on coat compartment bulkheads beside the buffets. These seats have shoulder harnesses as well as seat belts.

The stewardess call bell is a single-stroke chime, audible throughout the cabin. Three call lights, visible from the cabin, indicate whether the summons is from the passenger compartment, from a lavatory, or from the flight deck.

Handsets are installed at forward and aft stations, for communication with the flight deck or with the attendant at the opposite end of the cabin. A public address system may be used by the flight crew for announcements. The stewardess, by requesting the flight crew for the proper connection, can also make use of the public address system.

FLIGHT COMPARTMENT

Convair jet airliners are as considerate of the comfort of flight personnel as of the passengers. Pilot and copilot, for probably the first time in history, have as standard equipment contoured reclinable seats.

The fundamental seat framework is similar to that of the usual bucket-type seat; contouring is effected by shaping a cushion base of polyvinyl chloride foam, an energy-absorbing material that can be formed by use of ordinary woodworking machine tools. The shaped seats and backs are cushioned with polyether foam, making a seat soft enough for comfort, but with undiminished strength and shock resistance.

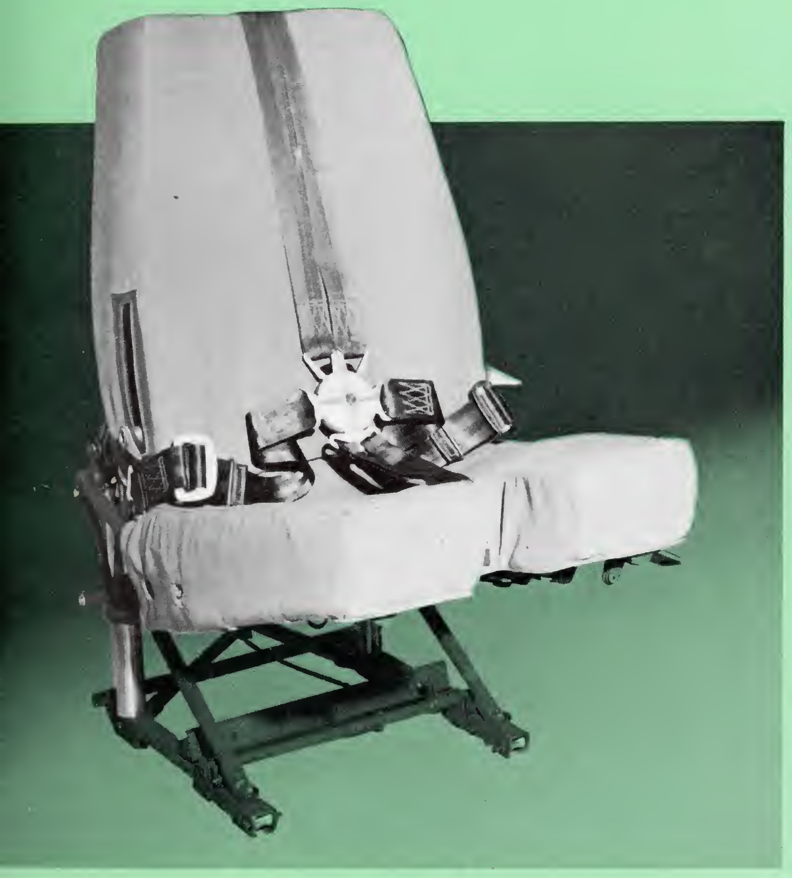
The seat has armrests, adjustable through a small angle. The entire seat is mounted on tracks and is adjustable through a seven-inch range fore and aft, and through five inches vertically. Shear pins, operated by fingertip controls, hold the seat in the selected positions. A counterbalancing spring, capable of lifting the seat weight, allows the occupant to adjust seat height without leaving his station. Pilot and copilot seats are interchangeable.

By squeezing a catch on the armrest, the occupant may push the seat back to a 30° reclining angle. The seat back has provisions for a headrest if desired.

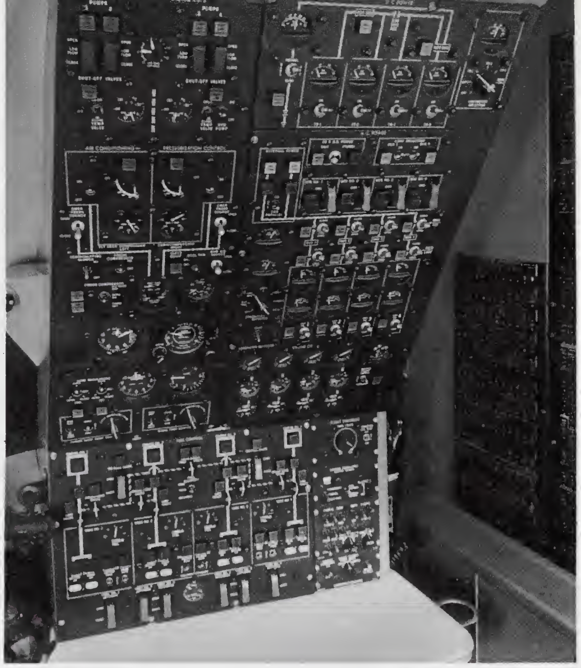
The flight engineer's seat is similar and is adjustable through the same ranges. Also, this seat swivels through 270° to face right, forward, or left. The tracks on which it is mounted are at a 45° angle with the airplane centerline, so that if desired the flight engineer may move up toward the center just behind the pilots and reach pedestal controls.

Pilot, copilot, and flight engineer seats are provided with seat belts, crotch strap, shoulder harness, and inertial reel. Belt, strap, and harness all fasten at one central fitting. Release catches are manipulated by a knob on the fitting; a twist of the knob, in either direction, unfastens all three.

If the airplane carries only one observer's seat, it can be placed back of the pilot and elevated, so that the observer may command a view of instrument panels and through the windshields. If provision must be made for a fifth man in the cockpit, the observer's seat may be moved inboard or outboard, and one of the seats may be designed to fold out of the way for access to the area.



Convair 880 Flight Engineer's Panel



The flight engineer on the Convair 880 is provided with an impressive group of panels containing more than seven square feet of instruments, lights, and switches. It is remarkable that such an array of dials and controls could be so simple despite its complex appearance, and a study of the panel quickly reveals the efficient grouping and placement of its different functions.

The flight engineer's panel is made up of several smaller panels, grouped in a pattern that best serves their purpose, and positioned in relation to the frequency of observation and adjustment by the flight engineer. For instance, the engine instruments which are under almost constant surveillance are at eye level and slightly to the right of the flight engineer. The hydraulic control panel, which requires only occasional attention, is located in the upper left-hand corner. The fuel control panel, containing the majority of controls and switches, is positioned at chest level within easy reach of the flight engineer.

Other systems represented on the engineer's panel are the air conditioning/pressurization control, electrical ac and dc power, and the communications panel. The flight engineer's lighting panel, his oxygen control panel, and his interphone panels are located in the lower right-hand corner.

The flight engineer's panel on the Convair 880 might be likened to a crossroads of information. It is here on his "interchange" that the status of numerous systems on the airplane can be determined at a glance. Flow lines and circuit diagrams that are integrated with appropriate groupings of instruments, switches, and lights facilitate the monitoring of these systems. On the fuel control panel, the entire fuel system of the 880 is diagrammatically laid out on the surface. Controls and switches are positioned on the diagram just as valves and control units would be found in the actual fuel system. When a marker on a dial lines up with the diagram, fuel flows through at that particular point; when the marker is perpendicular to the diagram, the fuel is off.

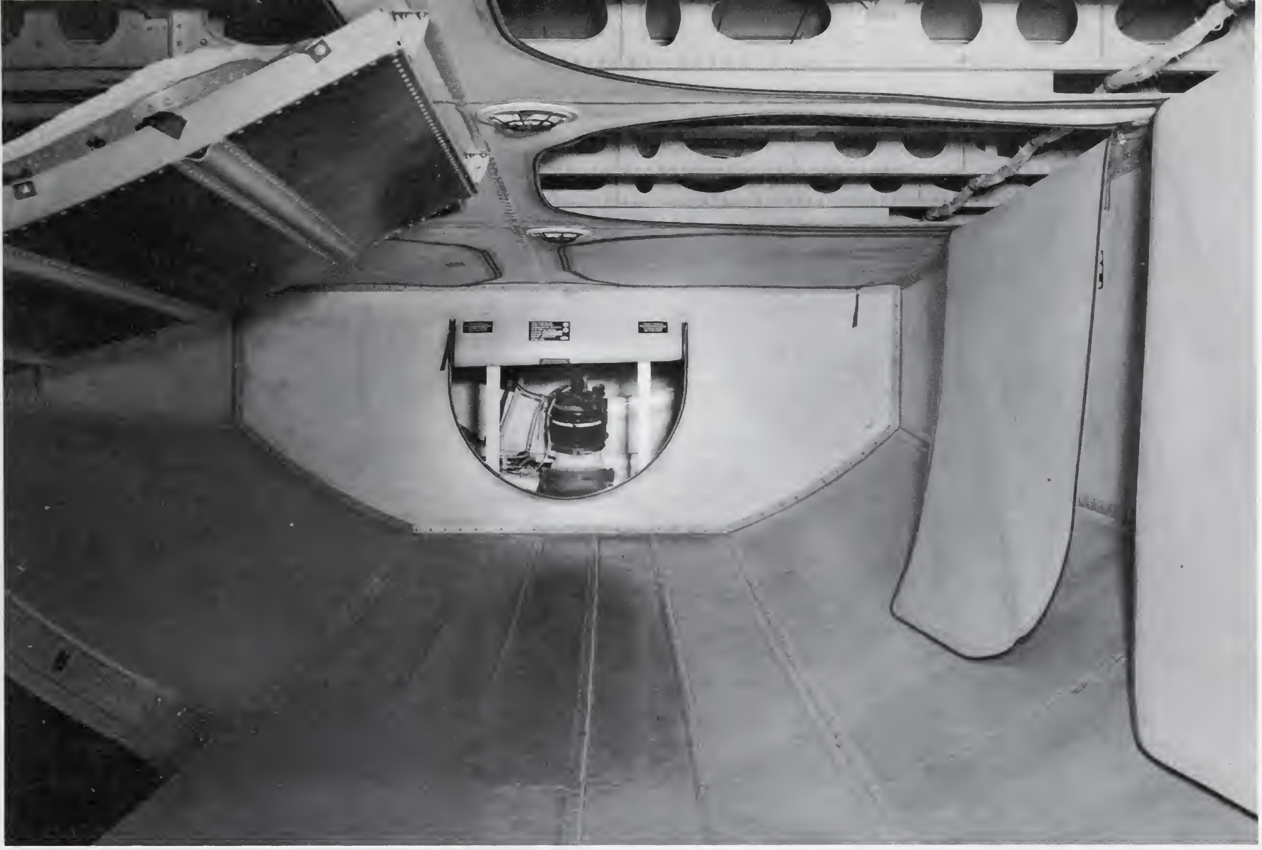
The flight engineer's panels are manufactured to customer requirements and vary slightly in arrangement and content. Basically, the specifications are the same for the different airlines, and all incorporate Convair-developed design improvements. One notable improvement is the advanced installation design. To facilitate checkouts and maintenance, each group of panels, of which there are five, hinges outward exposing the underside for easy access. In an emergency, this can be accomplished in flight.

The pilot's and copilot's instrument panels on the 880 are illuminated by soft indirect lighting, while the engineer's panel is lighted by a system called "edge-lighting," due to layout requirements. To protect the crew's night vision during night flying, cockpit lighting is kept soft and at a minimum. This is essential to flying safety. After the crew has become accustomed to darkness, and acquired their "night vision," any bright or sudden light would lessen their ability to see in the dark, and it would take several minutes to regain that vision.

An edge-lighted panel is one in which light is transmitted by refraction through a clear transparent core. As with indirect lighting, edge-lighting enables instrument openings, switch locations, and callouts on the surface to be easily read either day or night without reflections or glare. In some cases, the instrument dials themselves are edge-lighted. The "880" panels are made of clear acrylic plastic opaqued with dull black except for lettering, diagrams, and switch and instrument openings. Around the switches and instruments, a thin ring of light is permitted to shine through to softly illuminate the immediate area.

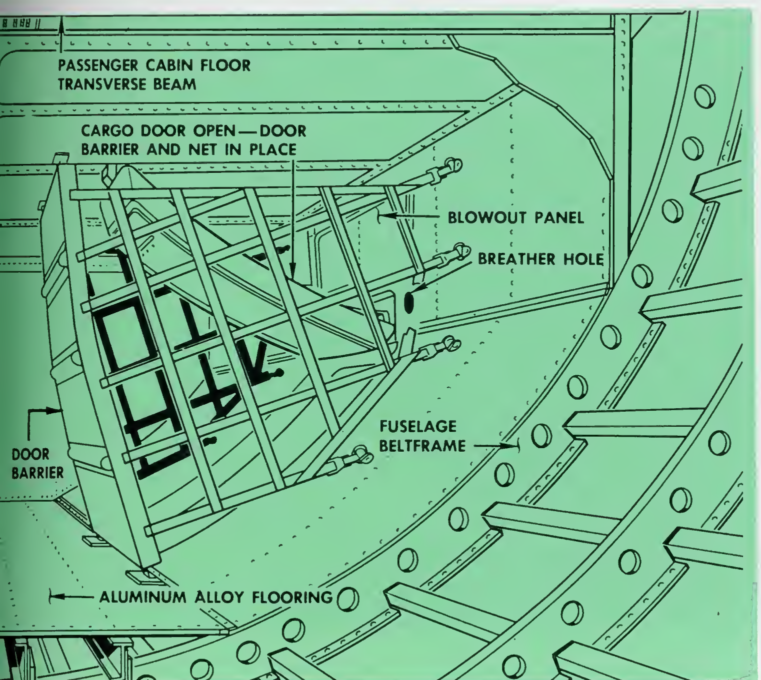
The panels are illuminated by minute electric bulbs, about the size of a pea, that are inserted into sockets fastened in the plastic. These lamps are carefully positioned a few inches apart to insure an even lighting and to prevent "hot spots" and faded-out areas. An interesting feature of these small lamps is the circuitry that supplies their current. The lamps are inserted into the socket bulb first, making one electrical contact through a metal ribbon extending along the inside of the socket. A light-tight cap is placed over the socket, making contact between the center of the base of the bulb and a second ribbon leading through the panel. The sockets are connected by printed circuits of sintered silver material, which is silk-screened on the back side of the panel and embedded into the plastic, flush with the surface.

External electrical contacts of the edge-lighted panel are small bare plugs protruding from the back of the panel. The plugs mate into receptacles attached to a metal back-up plate to which the panel is fastened. Instruments, switches, and warning lights are also mounted on the back-up plate and fit through openings cut out of the edge-lighted panel. The back-up plate in turn is mounted to the airplane structure by corner screws and a hinge that enables it to be swung outward.



Convair 880 Cargo Compartments

An outstanding feature of the Convair 880 jet airliner is its ability to hold servicing and turnaround times to a minimum during airport stops. One important aspect of this expeditious ground operation is the accessibility of the two cargo compartments, and the ease and speed with which these areas can be loaded and unloaded. The forward cargo area has a capacity of 448 cubic feet; the aft cargo area, 415 cubic feet.



Both the forward and aft cargo compartment floors are less than five feet from ground level, and each is accessible through a large door (approximately 34 inches by 39 inches) that opens inward and upward. The forward area is located between fuselage stations 375 and 603, and the aft area is between fuselage stations 1002 and 1230. The door for the forward compartment is forward of the wing at fuselage station 489, and the aft door is aft of the wing at fuselage station 1116. Both doors are on the lower right-hand side of the fuselage and are held in the closed position by bayonet-type latches. Lights in the pilots' compartment indicate the latched or unlatched position of the cargo compartment doors.

Each door is provided with a door hold-open mechanism consisting of a spring-loaded hook, attached to the lower inside edge of the door, and a cam on the lower end of the bayonet latch actuating shaft. When the door is raised, the spring-loaded hold-open hook engages a pin in the top of the cargo compartment. The door control handle may be pushed back into its recess without releasing the door hold-open mechanism. To unhook the door hold-open mechanism, the door control handle is rotated outward from its recess. This causes the cam on the bayonet latch actuating shaft to rotate and actuate the hold-open hook. The hold-open hook then releases and simultaneously the bayonet latch pins are pulled in, allowing the door to be lowered into the closed position.

Each cargo compartment is provided with several flush-mounted lights in the compartment ceiling that are illuminated by the action of a microswitch when the compartment door is opened. A protective grill

over each lighting fixture prevents luggage or cargo from becoming scorched, if placed close by. A small light at the top, and just inside, of each cargo door opening, also illuminates by action of the door micro-switch. Lights are arranged so as to illuminate the compartment, the doorway, and approximately 18 square feet of ground area near the door.

The ceiling, ends, and inboard sides of the cargo compartments are lined with heavy-duty neoprene-coated fibreglas cloth curtains that are held in place by attach strips and screws. These curtains can be unzipped for access to adjacent structure, and for maintenance of control cables, electric and electronic harnesses, and hydraulic tubes that extend through the lower part of the airplane fuselage.

To prevent shifting cargo from blocking the entrance to the cargo compartments, each opening is equipped with a fibreglas barricade that hinges from the compartment ceiling and snaps into place by spring-loaded pins that seat into the compartment floor just inboard of the door opening. To open, the barricade swings up and outward and hooks to the edge of the open compartment door.

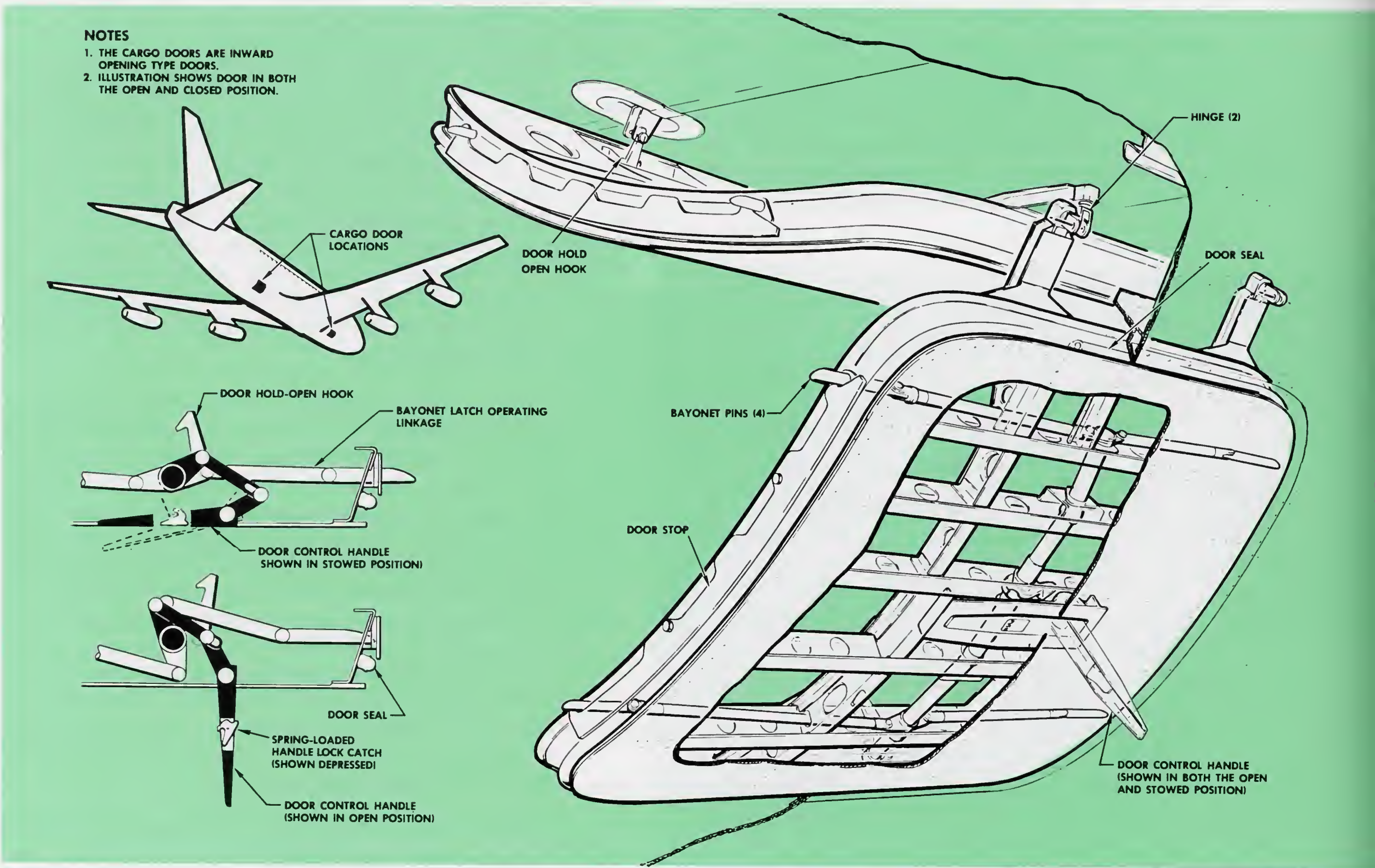
The barricade is equipped with nylon webbing at the sides of each compartment door opening to further prevent cargo from blocking the entrance.

The floors of the cargo compartments are constructed of 0.045 inch thick aluminum, and are capable of withstanding static loads of 100 pounds per square foot or 20 pounds per cubic foot. Nylon skid rails, extending fore and aft, are attached to the surface of the compartment floors. The floors are insulated from direct contact with the outside structure of the airplane by fibreglas angle supports.

The Convair 880 cargo compartments are heated indirectly by circulating air that passes between the compartment lining and the adjacent insulated structure. The compartment temperature is kept above 32° F to prevent cargo from freezing.

To comply with "FAA Defined" Class D requirements, the air inside the cargo compartments is static, except for breather provisions between the cargo compartment and the passenger cabin. This is accomplished by a small circular opening 2.75 inches in diameter, connecting the compartment with the cabin. Should combustion occur in a compartment, the static air condition would prevent the fire from spreading. As soon as the existing oxygen is consumed, the fire would be smothered.

The "880" cargo compartments are completely pressurized, an important requirement for the high altitudes the jet airliner will be flying. As with the passenger cabin, the cargo compartments maintain a pressure environment equivalent to 8,000 feet altitude. This feature protects delicate cargo, and eliminates the embarrassing aftermath of broken cosmetic containers and leaky fountain pens left to the mercy of extreme altitude pressure changes.



Convair 880/990 Oxygen System

. . . high pressure oxygen is immediately available in an emergency . . .

Convair 880/990 jet airliners have pressurized cabins that do not usually require supplemental oxygen. But, as protection for the flight crew and passengers in case of emergency, the aircraft is equipped with a high-pressure, 1800-psi gaseous oxygen system. In the event of rapid decompression, oxygen is immediately available for all occupants of the airplane.

From an altitude of 41,000 feet, the Convair 880/990 airliners can descend to an altitude of 17,000 feet in three minutes. At 17,000 feet altitude, the flight crew and passengers have available continuous oxygen for a period of 15 minutes; at an altitude of 14,000 feet, the flight crew has oxygen available for one hour and 45 minutes, and there is sufficient oxygen for 10 percent of the passengers for a duration of 30 minutes. One member of the flight crew is on oxygen at all times above an altitude of 25,000 feet, or 35,000 feet, depending on type of oxygen mask used.

The main oxygen supply storage cylinders are installed on the left side of the flight compartment, aft of the pilot's console. The cylinders have a capacity of 74 or 107 cubic feet, and weigh approximately 33 or 44.8 pounds, respectively, depending on customer requirements. Each is charged to 1800 psig.

The cylinders are equipped with slow-opening valves to prevent pressure surges in the system. A safety disc, built into each valve, is designed to rupture at a pressure of 2475 to 2775 psig. In the event that a safety disc should blow out, the entire contents of the cylinder will dump overboard, ejecting a green blowout disc. The green disc is normally visible from outside the airplane; if the disc is not visible, it is an indication that at least one oxygen cylinder has discharged overboard. A gage, which is an integral part of each cylinder valve, is mounted on the upstream side of the valve, indicating the contents of the cylinder.

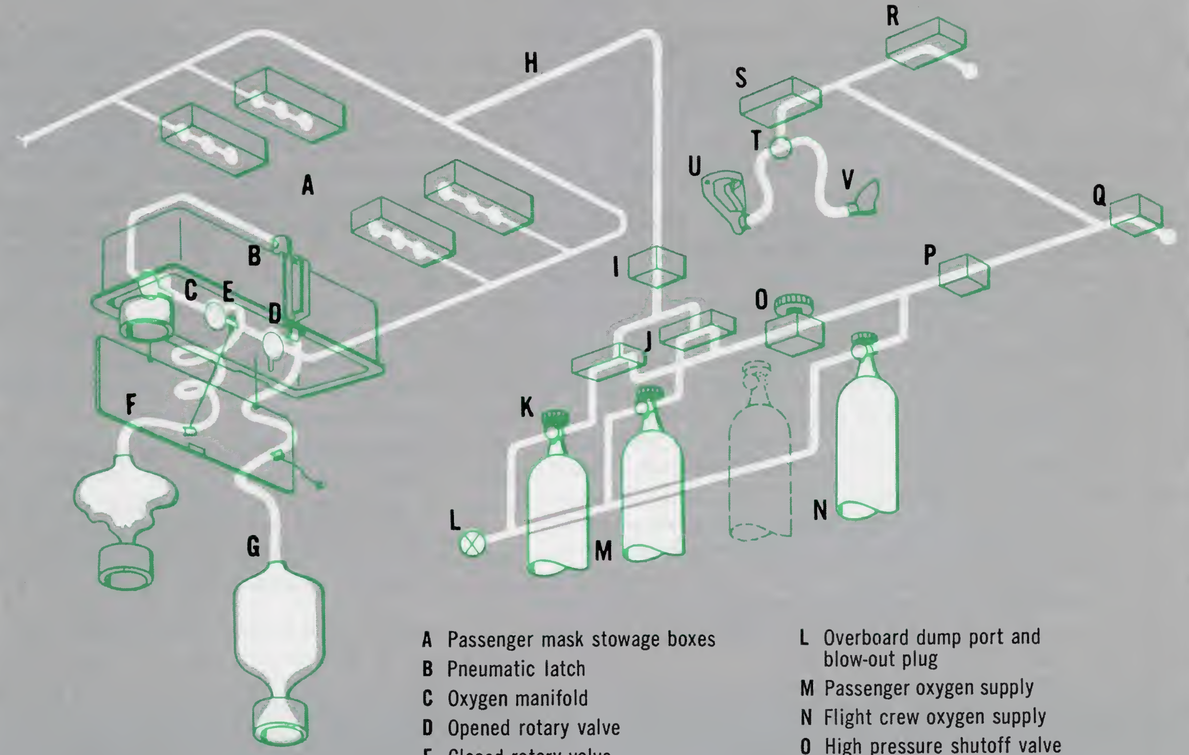
The flight crew is normally served by the forward cylinder; the passenger compartment by the aft cylinders. The flight crew and passenger systems are connected by a high-pressure line valve that can be opened to enable the flight crew to draw on the passenger oxygen supply, should the necessity arise.

The pilots and flight engineer are supplied with a diluter-demand type oxygen system, permitting individual crew members to manually select either diluted or 100 percent oxygen. The system is capable of continuous operation up to 35,000 feet, and limited operation at an airplane altitude to 41,000 feet.

Each location in the flight compartment (with the exception of the observer's position on some versions) is equipped with a regulator; a half-face oxygen mask; goggles, or a full-face smoke mask; and a mask selector valve. On those aircraft that have a third pilot's position, a half-face oxygen mask, a pair of smoke

Main oxygen cylinders in 880M/990 with provisions for fourth cylinder. Mask shown serves third pilot.

TYPICAL OXYGEN SYSTEM SCHEMATIC



- **A** Passenger mask stowage boxes
- **B** Pneumatic latch
- **C** Oxygen manifold
- **D** Opened rotary valve
- **E** Closed rotary valve
- **F** Mask deployed — no oxygen flow
- **G** Mask deployed — bag inflated
- **H** Oxygen line
- **I** Filter and bleed valve
- **J** Continuous-flow regulator valves
- **K** Slow-opening valves, pressure gages, and safety discs
- **L** Overboard dump port and blow-out plug
- **M** Passenger oxygen supply
- **N** Flight crew oxygen supply
- **O** High pressure shutoff valve
- **P** Pressure reducer
- **Q** Pilot's diluter-demand regulator
- **R** Copilot's diluter-demand regulator
- **S** Flight engineer's diluter-demand regulator
- **T** Selector valve
- **U** Smoke mask
- **V** Normal mask

goggles (instead of a smoke mask), and a mask plug-in connector assembly (in lieu of a mask selector valve) are supplied. On some versions, the flight engineer's station contains this same equipment.

Visual indication that oxygen is flowing through the regulator with each inhalation is shown by a flow indicator on the regulator.

A pressure reducer, installed in the supply line between the oxygen storage cylinder and the flight crew diluter-demand regulators, decreases the oxygen pressure from 1800 psig bottle pressure to 50-75 psig operating pressure.

The passengers, cabin attendants, and observer are served by a continuous-flow type system which operates automatically when the cabin pressure altitude exceeds 14,500 (±500) feet. When the system is automatically actuated, cup-type oxygen masks are released from an overhead panel, dropping a mask to hang approximately 11 inches in front of each passenger, cabin attendant, and observer position. A lanyard is attached to a plastic supply tube just above a reservoir bag, and hence to a clip on an actuating lever. A pull on the suspended mask turns a rotary-type lever down, opening the supply valve and allowing the lanyard to slip from the lever, further releasing the oxygen mask to a full 48 inches (72 inches on attendants' and lavatory masks) from the overhead compartment. With the supply valve open, oxygen enters the reservoir bag through perforations in the supply tube within the bag, and the mask is ready for use.

The compensated safety-dilution valve automatically permits cabin air and oxygen from the reservoir bag to be inhaled together. The reservoir bag, inhalation valve, and safety-dilution valve enable the passenger to inhale the proper air-oxygen mixture deeply without collapsing the face mask. During exhalation, the exhalation valve opens directly to cabin air. The

oxygen required for a cabin altitude of 10,000 to 41,000 feet varies from approximately 13 psig to 50 psig, being programmed by an aneroid-controlled automatic regulator.

Manual override levers on the automatic regulators may be actuated to provide regulated oxygen for the passengers at altitudes below the cabin automatic opening altitude.

The Convair 880M/990 passenger system has the following mask locations in the passenger cabin area: three masks in each of the convenience pods (overhead panels), located in the hatracks directly above the passenger seats (including versions with lounge); two masks in each double storage compartment above the lounge seats (in some versions). Additional mask positions in the cabin area are: two masks located in the ceiling of each lavatory (and buffet on some versions); three single masks for the use of cabin attendants — one mask in the forward entrance area (some versions have a double-mask stowage box for the forward cabin attendant); and two masks in the aft entrance area. Some configurations have a passenger-type mask installed in the flight compartment for the use of an observer.

The passenger oxygen mask is made of soft plastic, approximately four inches in diameter and three inches deep. It is formed like a cup to fit over the user's mouth and nose. It is reusable after sterilization. Attached to the mask is an elastic head band, an inhalation valve, an exhalation valve, a compensated safety and dilution valve, and a plastic reservoir bag with plastic supply tubing. An instruction illustration is printed on both sides of the reservoir bag.

To stow the masks after use, the stowage compartment door mechanism must first be cocked by pulling the door lock to the right against the spring until the bellcrank and holding arm are in the cocked position.

Passenger oxygen masks release automatically when needed. Model demonstrates functional use of mask.

Before the oxygen mask assembly is stowed, it is prepared in a manner that will allow it to fall free when the oxygen system is activated. The supply tubing is coiled into three or four four-inch diameter loops, permitting the mask to hang approximately 18 inches below the coil. The lanyard is then wrapped once around the coil, and the plug on the free end of the lanyard is inserted into the clip on the supply valve lever. The valve lever is then rotated to the closed position.

When all of the masks of one container are coiled and clipped, and all of the rotary valve levers are up in the closed position, the reservoir bag of each mask is wrapped around the head band and the resultant roll coiled around the top of the mask. The masks are then positioned in the stowage compartment so that the faces of the masks rest squarely on the inside surface of the compartment door.

Care must be taken when stowing the masks to prevent reservoir bags and tubing from becoming lodged between the masks and the compartment sides. After closing the stowage compartment door, the door latching mechanism must be checked for positive locking. *(See page 184 for oxygen mask stowage details.)*

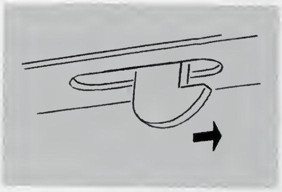
First-aid oxygen for passengers and a supplemental portable supply for cabin attendants and flight crew is provided by several portable oxygen cylinders that are located in the passenger compartment and in the flight compartment. The flight crew portable cylinder is equipped with a full-face mask for protection against toxic conditions. The portable oxygen cylinders in the passenger compartment consist of continuous-flow regulators having four-liter-per-minute flow bibs and two-liter-per-minute flow bibs. Each portable oxygen cylinder is equipped with two or more rebreather disposable masks. Placing the control handle in the ON position renders either type of portable oxygen system ready for use.

The flight compartment portable oxygen cylinders have a capacity of 310 liters (11 cubic feet), and the passenger compartment portable oxygen cylinders have a capacity of either 203 liters (7.15 cubic feet) or 310 liters, depending on customer's requirements.

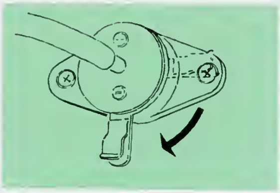
To assure safe, dependable operation of the oxygen system, extreme care must be exercised during assembly, installation, and inspection of the system. The following set of rules must be strictly observed:

1. Prior to working on the oxygen system, be sure that hands, tools, and clothing are free of grease or oil contaminants. No oil or grease substances shall be permitted on any part of the oxygen system.
2. When oxygen is being used for purging or for functional testing, open all cabin compartment doors and flight compartment windows to dissipate the enriched atmosphere of oxygen and air.
3. Do not smoke in the vicinity of any oxygen testing or purging procedures.
4. Do not loosen or tighten line fittings until all pressure has been bled from the system.

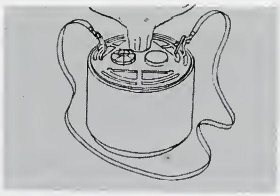
Passenger Oxygen Mask Stowage



1. Pull hook in direction of arrow to cock door latch mechanism.

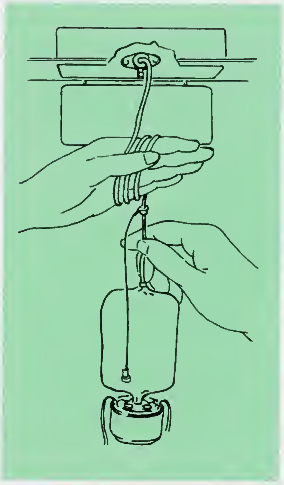


2. Rotate actuating lever on rotary valves to down (open) position.



3. Relocate head band clips to inner mask ring.

CAUTION:
PRIOR TO WORKING ON OXYGEN SYSTEM, SAFETY AND PRODUCT APPEARANCE DEMAND THAT HANDS, TOOLS, AND CLOTHING ARE FREE OF GREASE OR OIL CONTAMINANTS.



4. Grasp mask supply tube in left hand, about level with lower edge of open stowage box door.

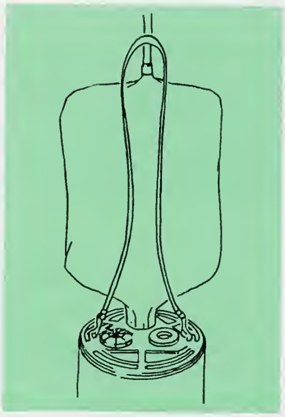
5. With right hand, coil supply tube around left hand. Form 3 or 4 loops approx. 3.5 inches in diameter.

6. Rotate left hand (holding coiled supply tube) to palm-up position.

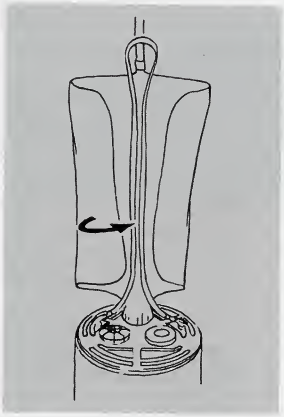
7. With right hand, grasp lanyard (attached to supply tube at yellow ferrule) and wrap lanyard around coils.

8. Push plug on end of lanyard into clip at end of rotary valve lever.

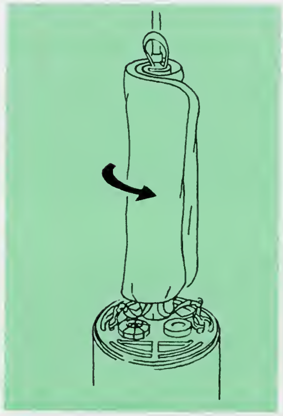
9. Rotate actuating lever on rotary valve to up (closed) position.



10. Smooth plastic reservoir bag. Place elastic head band in middle of bag.



11. Fold reservoir bag in half, around head band.



12. Roll folded bag from center to edge.

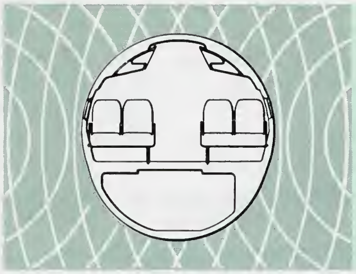
13. Starting with the most remote mask, coil rolled reservoir bag and supply tube hanging from the yellow lanyard ferrule.

14. Push mask and tubing straight up into box. Make certain that neither a part of bag nor tubing becomes lodged between mask and side of box. Any binding or lodging may prevent mask from falling free when stowage box is opened.

15. While holding stowed masks in box, insert door hooks into their respective slots.

16. Gently jostle door and settle tubing and masks in position (face of mask to be flush with door).

17. Close stowage box door. Ascertain that latches engage.



Fuselage Sound Attenuation

CONVAIR 880/990

Hushing the luxurious interior of the Convair 880/990 jet airliner to a sound level that will allow comfortable conversation between passengers has been achieved.

As the swift jet airliner speeds through the upper atmosphere at near sonic velocities, the sound of the air rushing over the skin tries to enter the fuselage shell. This aerodynamic sound, coupled with the noise created by the jet engine blast striking the aft portion of the fuselage, would become loud and annoying if left unabated. Inside the cabin there are additional sources of noise created by the ventilation system and the operation of auxiliary equipment. These, too, had to be subdued to attain a hushed cabin interior.

Convair acoustical engineers set about to achieve their goal of the quietest jet airliner in a manner that "left no stone unturned." Their greatest concern was in two types of sound: noise caused by the jet engine exhaust, and noise generated during flight by the friction of the air passing over the fuselage skin.

The decision to accept the design concept of a double wall construction for the passenger cabin to counteract aerodynamic noise was made early in the design stage of the Convair 880. This led to the adoption of a relatively heavy outer skin and inner trim panels of special sandwich construction with glass fiber blankets between the walls. The heavier outer skin not only resulted in improved low frequency sound attenuation, but also saved stringer weight by reducing the number of stringers required. The fiber glass blankets between the thick skin and the interior trim panels proved effective against the high frequency sounds.

It was also determined that the fiber glass blankets were more than adequate for thermal insulation and for the prevention of moisture condensation in the fuselage structure during rapid changes in temperature.

To further develop and refine the "880" sound attenuation program, Convair built a special acoustics laboratory facility. This laboratory consists of two buildings: the basic laboratory, and a fuselage section building. The basic laboratory has adjoining test rooms which represent the opposite in acoustic environments—an anechoic (echo-free) wedge-lined room, and a reverberation room with smooth hard walls to reflect back sound. Various cabin wall panels were placed between the two rooms, and tested for their noise barrier effectiveness.

A 19-foot section of the Convair 880 fuselage was placed inside the fuselage section building with the ends of the section carefully sealed to allow noise to enter only through the sides. Loudspeakers placed in the corners of the room were used to produce uniform sound fields over the entire outside of the section. Thus, any number of sound conditions could be simulated and tested inside the fuselage section.

By fully utilizing results from this development program, Convair was able to gain accurate knowl-

Thermal and acoustical insulation blankets are tailored to fit snugly around all windows and doors.

To facilitate inspection and maintenance, the blankets are installed outboard of wiring and plumbing.

Damping tape of aluminum foil is applied to the inside of the skin panels in the engine exhaust areas.

edge of material and component performance, and to develop new materials and installation methods. In carrying out a balanced design concept and reducing weight by refinement of design, Convair engineers pared off almost 25 percent of the weight from the original acoustical treatment allocation.

The thermal and acoustical insulation blankets, used to line the interior of the "880/990" are made from low density fiber glass matting. Composed of 0.00004 inch diameter glass fibers, these mats form, in most cases, four-inch-thick blankets. To safeguard against moisture, the blankets are encased in lightweight waterproof nylon fabric which is also Skydrol- and fire-resistant. Occasional small diameter breather holes are provided in the covering to assure even pressure throughout the blanket.

The double wall construction of the Convair 880/990, using interior trim panels in conjunction with outer skin, eliminated the need for internal septums within the insulating blankets. This resulted in blanket weight reductions up to 30 percent without lowering blanket insulating effectiveness.

The blankets are tailored to fit snugly between the fuselage beltframes and around windows and openings. Attached to one edge of each blanket section is a flexible flange which is wrapped around the beltframe and held in place by metal clips. This flange, in turn, holds the adjoining blanket edge in place while the opposite flange wraps around the following beltframe, and so on.

The blankets are installed outboard of all tubing, wiring, and ducting, thereby practically eliminating the need for disturbing the blanket placement during normal inspection and repair operations. Slitting or piercing the blankets is held to an absolute minimum to prevent sound leaks.

Nylon cords, criss-crossed against the insulating blankets, hold them firmly against the fuselage skin and prevent them from sagging. The blankets are attached to the airframe in this manner so that they can be easily removed to facilitate repair or maintenance of the fuselage structure.

In the aft portion of the fuselage, from the proximity of the wing trailing edge to the empennage, measures were taken to attenuate the noise of the jet engine blast. Successful results were obtained by applying a damping tape consisting of pure aluminum foil with a special adhesive to the inside of the skin panels between the beltframes before the installation of the fiber glass blankets.

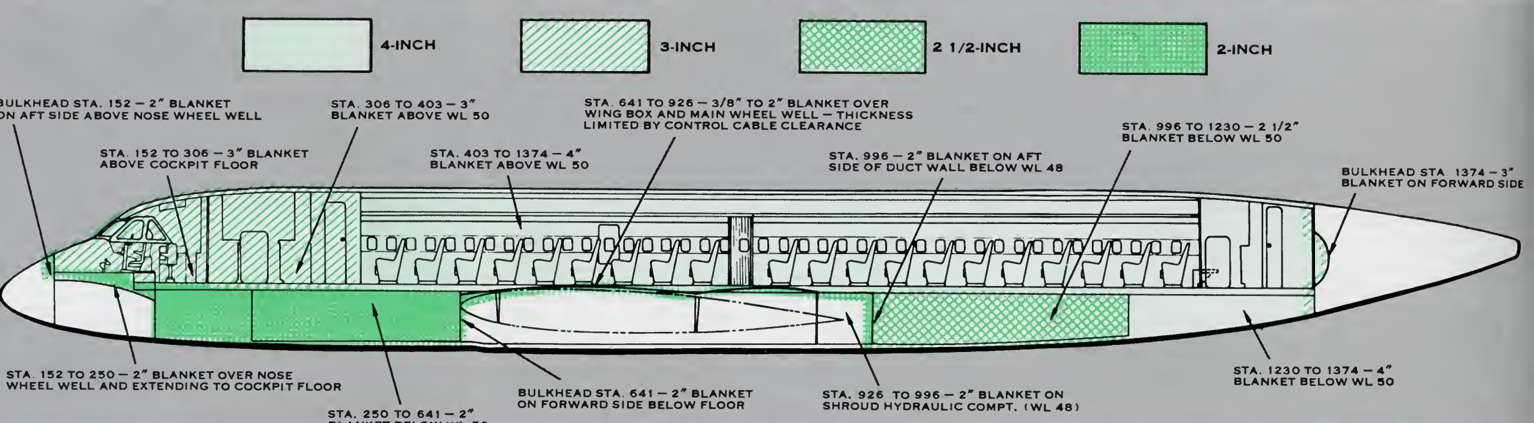
Varying in foil thickness from 0.008 to 0.012 inch, the damping tape is built up in different layers and schedules, depending on the location of the panel and the extent of damping required.

The passenger windows on the Convair 880/990 complement the insulating blankets and damping tape in the control of heat and sound. Each consisting of three panels separated by air spaces, the windows act as a very efficient thermal and sound barrier. To insure adequate quieting of jet exhaust noise, the windows in the aft section of the fuselage have thicker inner panels. As a further step in arresting sound, all inner window panes are mounted in soft rubber retainers.

The engine sound suppressors, although designed for external sound control, proved just as effective in reducing low frequency noise inside the aft portion of the cabin.

Fiber glass reinforced plastic is used extensively throughout the airplane as a thermal insulating medium between the primary airframe structure and interior installations. Rubber grommets are used between basic structure and interior trim to isolate vibration and to aid in overall sound attenuation. Interior trim brackets, and many other plastic fittings add to the cumulative result of an insulated interior.

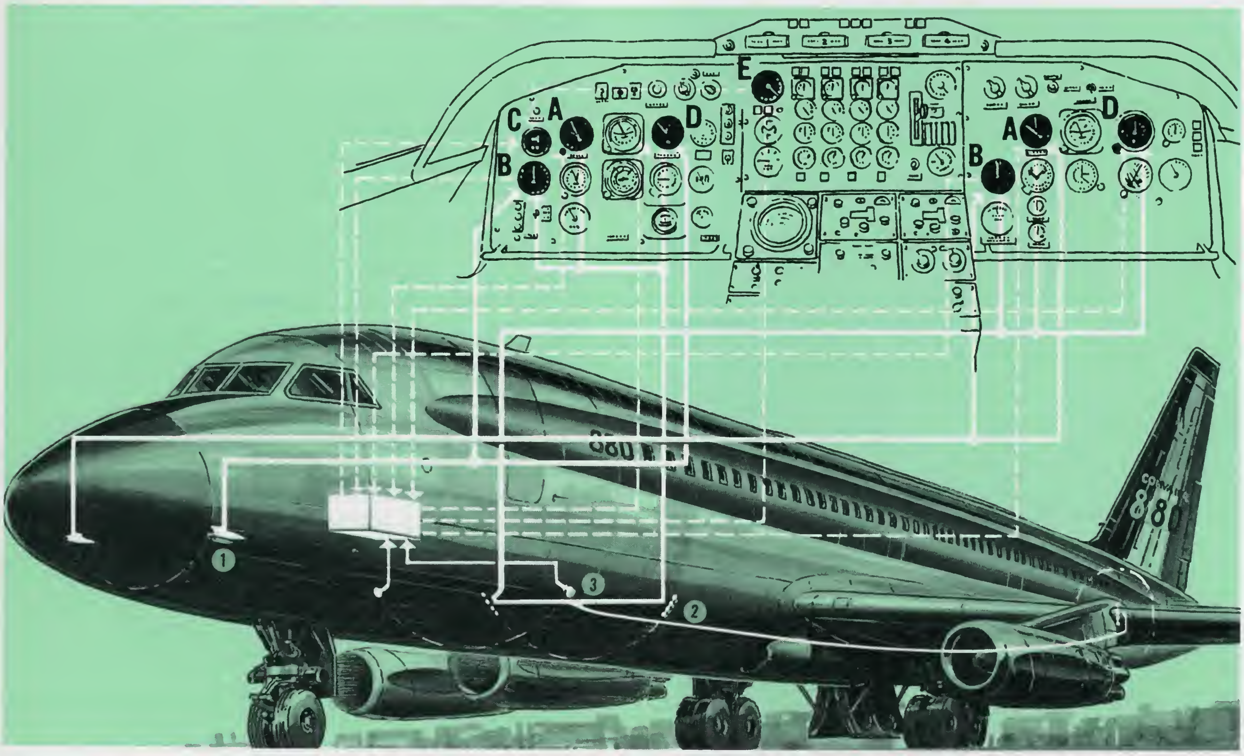
Upholstery, carpets, drapes, and even the passengers themselves contribute to the final hushed environment of the passenger compartment on the Convair 880/990—the quietest jet airliner.



BLANKET THICKNESS DIAGRAM

K.I.F.I.S.

Kollsman Integrated Flight Instrument System



Airspeeds, Mach number, outside air temperature, and altitude are computed from three sensors — pitot (1), static (2), and air temperature (3). Letters key pictures of instruments on pages 188 and 189.

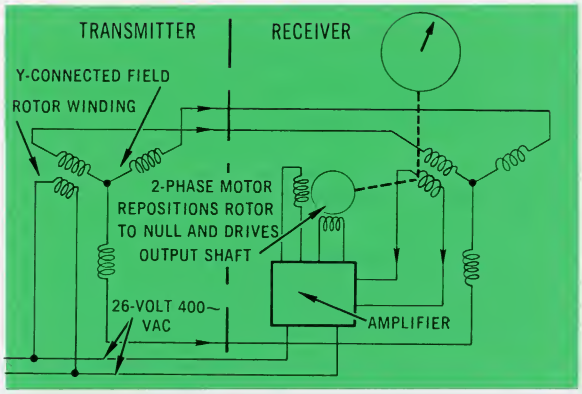
Airspeed and altitude indicators in the Convair 880 and 990 jet airliners are highly refined versions of instruments that have not changed in basic principles since man first began to fly. Speed and altitude are still gaged by measuring ram air and static air pressures with aneroid sensors. Corrections must be made for local barometric pressure, temperature, instrument installation, and side effects of airflow outside the airplane. From these corrected figures, true airspeed must be calculated and maximum or optimum flying speeds derived for the airplane at a given altitude.

The difference today is that the pilot no longer has to figure all this out with graphs and pencil and paper. The instruments make the allowances, do the multiplication and extract the square roots, and show him the answer at a glance. By mechanical and electrical contrivances, aerodynamic equations materialize as miniature levers, gear trains, and bridge circuits; the solutions are worked out in terms of shaft rotations, to move pointers around dials.

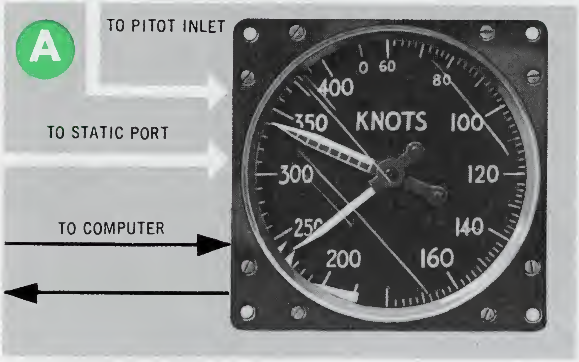
Part of the computation is done within the individual instrument housings behind the flight compartment panels. The rest is performed in a computer unit in the electrical compartment, which interrelates the data from Machmeter, altimeter, and static air temperature bulb.

Five instruments — indicated airspeed, Machmeter, altimeter, true airspeed, and static air temperature indicators — make up the Kollsman Integrated Flight Instrument System, sometimes abbreviated to KIFIS. The three pressure-actuated instruments — airspeed indicator, Machmeter, and altimeter — are basically of standard design; without electric power, they will function as uncorrected conventional instruments, eliminating the need for standby instrumentation for use in event of power failure. The true airspeed and outside temperature indicators are dependent on electromechanical sources. Electrical data is available from the KIFIS for use with other flight or navigation instruments.

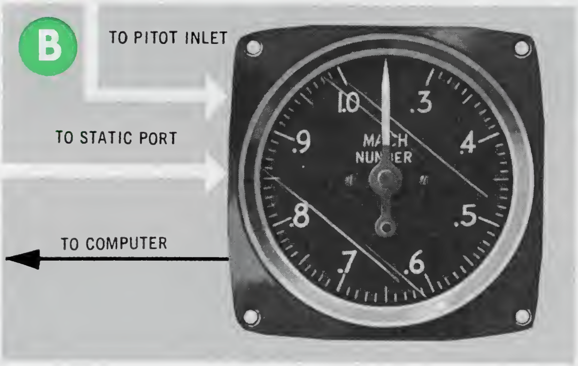
There are duplicate Machmeters, airspeed indicators, and altimeters — one set for pilot and one for copilot. Computer elements for these instruments are also duplicated, so that malfunction of one set does not affect the other.



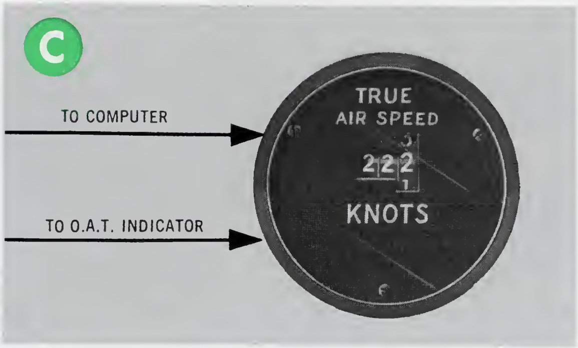
Synchrotel transmits data. Output shaft may operate instrument pointer or a computer rotor.



IAS indicator maximum-allowable pointer varies to show maximum speeds at various altitudes.



Machmeter provides output for use in computing true airspeed, true temperature, and altitude.



True airspeed indication, on pilot's panel only, is computed from Mach number, temperature.

The data from which the instruments operate come from pitot and static pressure ports, an angle-of-attack sensor, and a temperature bulb. Two pitot heads are located on the under side of the fuselage outboard of the nose wheel well doors. Pilot's Machmeter and airspeed indicator are supplied by one, the copilot's flight instruments and certain other instruments and equipment are connected to the other.

Flush static ports for pilot and copilot, and also for autopilot and pressurization systems, are located on each side of the lower fuselage between the forward cabin doors and the wing. An alternate source of static pressure is the unpressurized tail cone, available by actuating flight compartment static selector switches. The angle-of-attack and temperature sensing units are on the left-hand side of the fuselage in the slipstream.

The electrical portion of the Kollsman system utilizes transmitter-receiving units of the synchronous motor type (Kollsman trade name Synchrotel), of which a basic schematic is presented herein. The rotor elements, one of which is usually connected to an instrument handstaff, are energized by 26-volt 400-cycle a-c. Wye-connected field windings are paralleled as shown.

Identical field polarities are set up by induction in both units by the energized rotor windings. As the transmitter rotor is turned by the mechanism, shifting polarity in the transmitter field is duplicated by an identical shift in the receiver control transformer. This results in an error signal (in the receiver rotor) which is amplified and applied to the servo motor, causing it to duplicate the rotation of the transmitter. In this way, information can be conveyed between sensors, computors, and indicators.

Following are descriptions of the individual indicators, with some added discussion of the compensating mechanisms and circuitry.

The Machmeter indication is one that is not electrically computed or corrected. Pitot and static lines lead into the case, and diaphragms actuate a computing mechanism that yields a dial reading in Mach number — ratio of true airspeed to speed of sound at the airplane's altitude. The dial reads from 0.3 to 1.0, with a radial red line, which marks Mach 0.89 in "880" aircraft, Mach 0.91 in the "990."

Mach number has a direct relationship to errors inherent in temperature and static pressure sensing in a moving airplane. Therefore, the Machmeters include Synchrotel transmitters to make Mach number information available to the computers.

The basic outside temperature sensor is a resistance type bulb, mounted flush in the aircraft skin. The outside air temperature indicator is mounted on the left side of the instrument panel and is calibrated from −100° C to +50° C.

The indicator uses, from the computer, a resistance value determined by Mach number and, by a bridge circuit, combines it with the information from the temperature bulb to provide a true reading. In the indicator is a potentiometer which provides a resistance, determined by outside temperature, to be used by the true airspeed indicator.

True airspeed is computed from Mach number and from outside temperature. The true airspeed instrument therefore receives its information directly from the air temperature indicator and from a Mach function derived in the computer. The instrument is mounted on the pilot's instrument panel. The reading is in digital form.

The IAS indicators — one for pilot and one for co-pilot — provide readings of indicated airspeed and for maximum allowable (Normal operating or V_{no}) speed.

The indicated airspeed reading is conventional, derived from a differential pressure mechanism that uses pitot and static pressures on a diaphragm to actuate a pointer calibrated in knots IAS.

Maximum allowable speed is indicated by a color-banded needle that is actuated by an altimeter-type static-pressure-measuring diaphragm. The maxima are in terms of equivalent airspeed up to a specified altitude, and in terms of Mach number above this level.

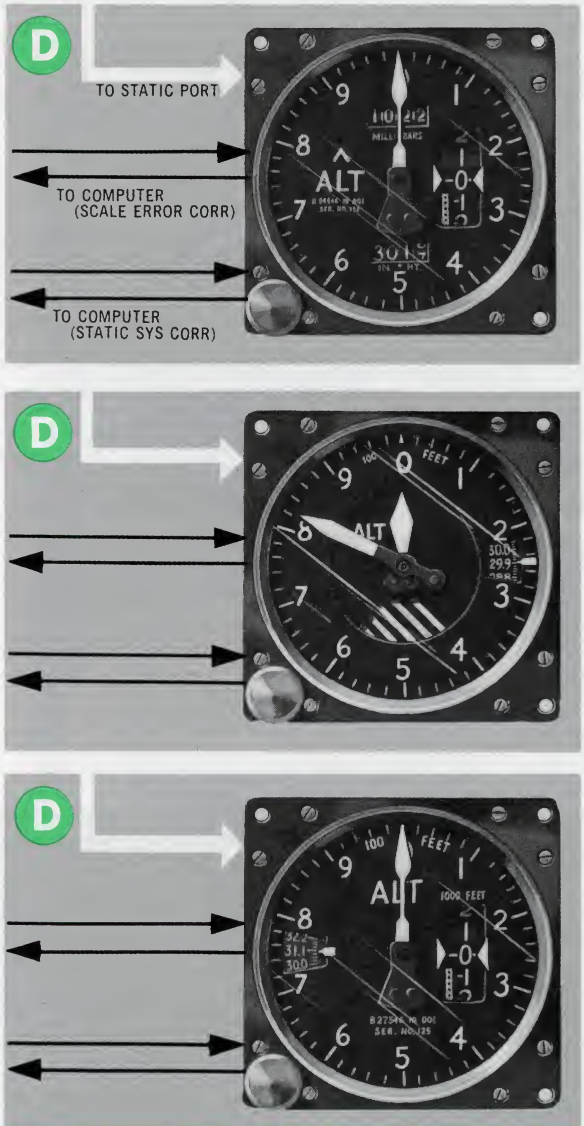
In the "880," the needle is calibrated to indicate maximum allowable speed in terms of the IAS resulting from a constant EAS of 375 knots up to approximately 22,900 feet, and in terms of Mach 0.89 above this altitude. In the "990," the maxima are in terms of the IAS resulting from an EAS varying from 375 knots at sea level up to 395 knots at the specified altitude (somewhat lower than for the "880"), and in terms of Mach 0.91 above this level. The needle will therefore normally move upward as the airplane climbs to the specified altitude, and then downward as IAS drops with constant Mach at higher altitudes.

Physical faces of the altimeters vary with customer preferences. Some 880 aircraft will have the conventional three-pointer dial, others the newer single-pointer dial with thousands of feet in a digital reading.

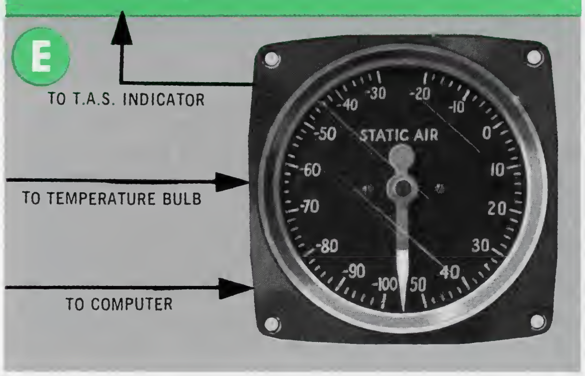
All Convair jet airliner altimeters, however, incorporate finely calibrated error corrective devices. One corrects for errors in the static pressure sensing system. These errors, standard in altimeters, are, for practical purposes, primarily a function of Mach number. The mechanism centers about a three-dimensional cam, located in the computer unit. The Machmeter Synchrotel transmits a signal to the computer, which is used to operate a servo to rotate the cam as a function of Mach number; the cam follower rides on the periphery of the rotating Mach cam, producing a signal proportional to static system error correction.

This signal is added to the output of a servo which compensates for error in calibration of the altimeter itself. The sum of these error corrections actuates a servo which rotates the diaphragm-operated altimeter mechanism, so that corrected altitude is shown on the dial. The Kollsman company claims an accuracy from within ±30 feet at sea level to within ±80 feet at 30,000 feet.

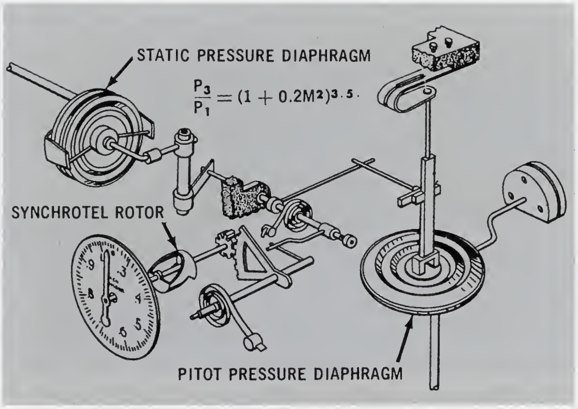
For those without technical background in recent instrumentation, the functional schematic diagram may give some general idea of how fairly complex algebraic formulas are given concrete form in mechanical and electrical devices.



These three types of altimeters are all being used in Convair 880 and 990 aircraft, depending on the preferences of the individual airlines.



Static air temperature (outside air temperature) indicator is on the center instrument panel.



MACHMETER OPERATIONAL SCHEMATIC

The word "computer" may bring to the layman's mind a picture of a ceiling-high array of blinking lights backed by miles of wiring and dozens of vacuum tubes. A computer may be as simple as a torque wrench. In the schematic exploded view of the Machmeter can be seen an indication of how

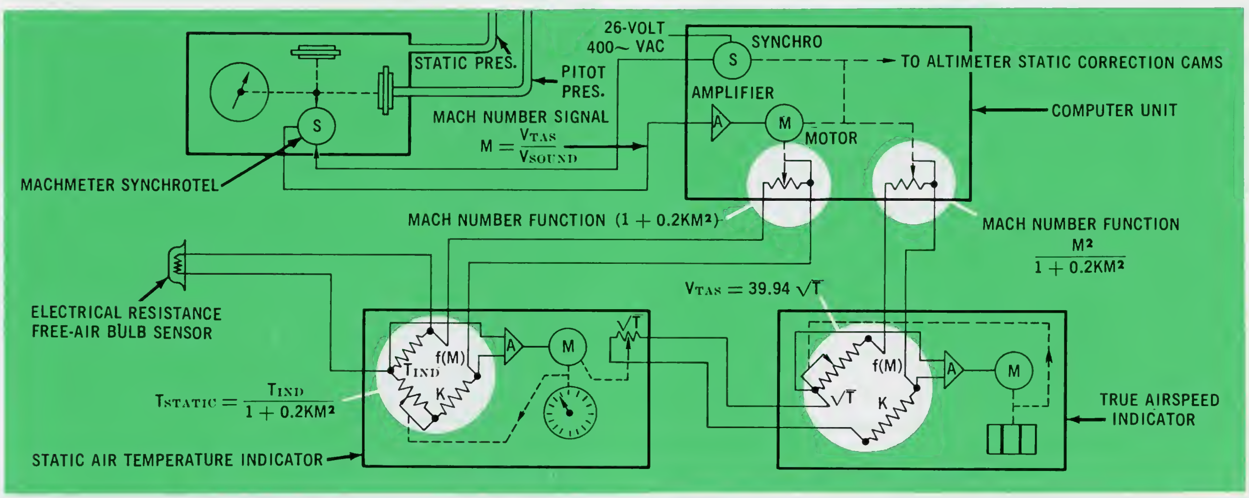
$$\frac{P_3}{P_1} = (1 + 0.2M^2)^{3.5}$$

looks in purely mechanical form.

accomplished by a bridge circuit, of which one leg is the Mach function; a second leg, the signal from the airstream sensor; a third leg, a calibrating resistor; and the fourth leg, a follow-up potentiometer. The motor that positions the follow-up potentiometer operates the instrument pointer to show true outside air temperature.

True airspeed is computed from Mach number and temperature by the equation $V_{tas} = 38.94M \sqrt{T}$. M comes from the computer, as stated; $\sqrt{T}$ is supplied by the temperature indicator, through a second potentiometer operated by the servo motor which operates the temperature pointer. The equation again is solved by a servo-balanced bridge circuit, the two functions forming two legs of the bridge; a calibrating resistor, the third leg; and a follow-up potentiometer, the fourth leg. The resulting signal drives a motor that operates counters to present true airspeed in digital form.

This type of computer is ingenious rather than complex, and demands a high degree of accuracy in both mechanical and electrical elements. Pinions are hardened steel, bearings are jeweled, dimensions and resistances are finely calibrated. Electronic elements are completely transistorized. To obtain utmost accuracy, a few parts of the system have been matched to certain other units, and care must be taken to see that such parts are not interchanged.



FUNCTIONAL SCHEMATIC (PARTIAL) showing how Mach number and ambient temperature are used to correct indicator readings

The Mach number (M in the formula), which expresses the ratio of true airspeed to the speed of sound, is relayed to the computer by Synchrotel. There, the receiver unit operates a pair of potentiometers, which provide two electrical outputs: a resistance equivalent to Mach function $(1 + 0.2KM^2)$ for use in computing true static outside air temperature from the reading picked up by the temperature sensor; and a different Mach number function M for use by the true airspeed indicator.

Static air temperature is the indicated air temperature divided by the function $(1 + 0.2KM^2)$. This is

Flight Data Recorders

. . . Taped records supply second-by-second account of every "880" flight . . .

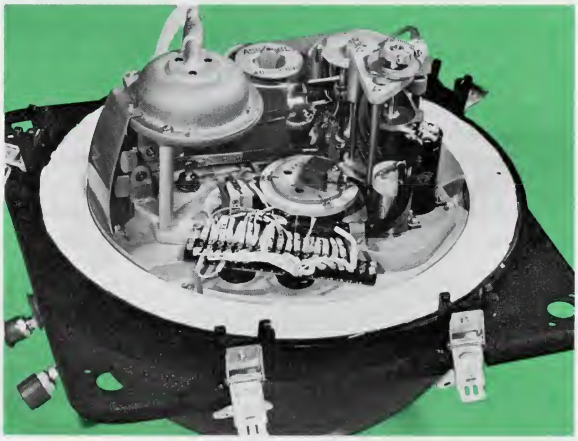
All commercial aircraft certificated to fly above 25,000 feet are required by the FAA to be equipped with a device that automatically records certain flight data. Soon, all turbine-powered aircraft (including turbo-props) weighing more than 12,500 pounds gross will be so equipped. The basic requirements are set forth in Technical Standard Order FAA TSO-C51: the device must record continuously from takeoff through landing — or at least once a second — the altitude, indicated airspeed, compass heading, and vertical acceleration; and the record must be capable of surviving a crash and fire.

Specifically, with respect to the latter requirement, the instrument must preserve its record intact after an impact of 100 g's; after submersion in salt water for 36 hours; and after subjection to heat of 1100°C (2012°F) for 15 or 30 minutes (depending on type of heat) applied over half the exterior surface.

Obviously, the regulation is officially concerned with the causes of disaster. Airline operators, however, are finding another aspect of interest — the second-by-second records of more or less normal flights. Even the minimal data required may be valuable in evaluation of high gust loads or landing shock in their effects on structures. Also, since the recording apparatus must be provided, it can be designed for expansion to keep records other than those demanded by regulation.

General specifications for two types of recorders, oscillographic and magnetic tape, have been drawn up by ARINC (Aeronautical Radio, Inc., an association of manufacturers and operators that sets standards recognized by the trade). The term "tape recorder" is, of course, familiar; "oscillographic" merely describes the common type of chart used in seismographs or furnace heat records, for example, in which a line is continuously drawn on a graph to represent amplitude of earth tremors or temperature vs time.

The LAS (Lockheed Air Service) recorder, flying on many "880" aircraft today, is designed primarily to meet minimum FAA requirements, and is relatively simple. It is housed in a split spherical shell, mounted in the hydraulic compartment or on structure just aft of the forward cargo compartment. Altitude, airspeed,



Spherical shock-proof, fireproof shell houses LAS recorder. It is mounted near airplane CG.

and vertical acceleration sensors are all within the unit, each mechanically linked to a stylus. A fourth stylus is positioned by a synchro, driven by the transmitter in a compass indicator. Altitude and airspeed sensors are connected to the copilot's pitot and static systems.

In the standard Convair installation, the recorder begins operating when external electrical power is disconnected after engine start. The recording medium is aluminum foil. The three styli for heading, altitude, and airspeed utilize the full width of the foil, so that the recording lines may cross each other. The compass heading is calibrated to 180°, rather than 360°, doubling the resolution factor. A binary (on-off) coding indicates which half of the azimuth the heading is on; a stylus contacts the foil to make a straight line for the "on" phase, and lifts for the "off" phase. To read the record, a transparent overlay, bearing the calibration, is placed over the graph. Along one edge are 1- and 15-minute time markers. Digital information, such as flight number and date, can be added by optional coder.

A East-west code tracing
B Airspeed (read inverted)
C Vertical acceleration
D Heading
F Pressure altitude
G Time marks

This is LAS record of an actual flight. "880" took off at San Diego to west; climbed toward west; turned east and leveled off; made S turn back toward west; resumed course and climbed to cruise altitude; flew east to El Paso; circled field to left and landed toward southeast.

The spool holds 100 feet of foil, enough for approximately 150 hours of operation. The foil is pulled past the styli at a steady rate by an escapement mechanism. The motor that drives the escapement operates through a spring, so that recording of all parameters except heading continues for ten minutes after power is cut off. A small microphone in the unit is connected to the airplane intercommunications system; by listening for the sound of the escapement, the crew can check that the recorder is operating. In one installation, a signal generator is substituted for the microphone.

In addition to "crash recorders," two "880" aircraft are now carrying NASA VGH units which record essentially the same data. The VGH (Velocity, Gravity, Height) records are for collection of operating statistics, relative to gust loadings. The units are supplied by NASA (National Aeronautics and Space Administration), and the records are returned to NASA for processing.

This unit is interesting because of its method of recording. The medium is a 70mm strip of photographic paper. The two pressure-sensitive elements — the synchro from a remote-mounted accelerometer, and a timer — actuate mirrors that reflect a lamp image through a 0.003-inch slit across the recording medium. The record resembles that of the LAS recorder, with a high degree of resolution for accuracy.

A somewhat more complex oscillographic recorder, meeting TSO-C51 and ARINC requirements, but with capability for expanded utility, is made by the Technical Products Division of the Waste King Corporation. This unit is sized for mounting in the ARINC standard ATR rack, and will normally be mounted in the electronics compartment. One component, the accelerometer, must be mounted near the airplane center of gravity without shock mounts; it is supplied as a separate unit. Airspeed and altitude sensors operate their styli mechanically. Heading and acceleration sensors are linked to the styli through synchros.

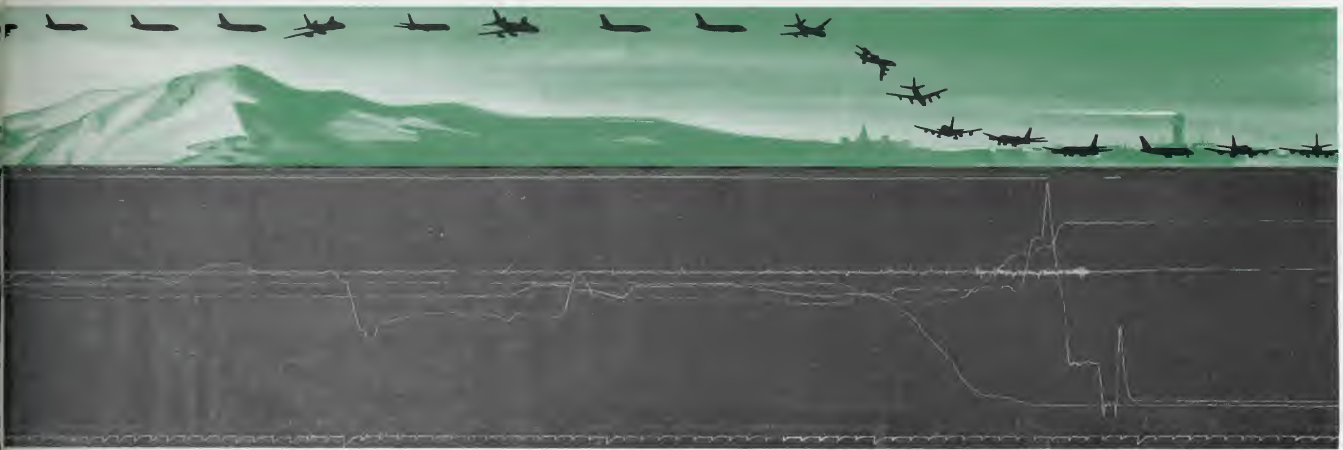
In this recorder, the medium is stainless steel foil with a black high-temperature-resistant coating, approximately 5 inches wide and 150 feet long. It is divided into four strips for the required four parameters. The stylus tracings do not cross each other; the calibration can therefore be scribed on the foil surface. The tracings are made by diamond scribers on the styli, which are pressed down periodically to cut through the foil coating, leaving a bright line 0.002 inch wide. The foil moves at the rate of six inches per hour. Since the scratches are made at half-second intervals, the typical tracing appears as a solid line, thin enough to be read with the required accuracy, even though the calibration band width is comparatively narrow.

The foil for this unit is coated on both sides. It can be turned over and run through again, doubling the time of recording per spool (from 300 to 600 hours); with proper readout equipment, it can be used for double scribing on both sides, thus allowing 1200 hours of operation per spool.

The styli are recording only 20 percent of the half-second interval, and float the rest of the time. Since vertical accelerations, as from gusts or landing, are of brief duration, the acceleration recording circuit requires a half-second memory in order to record peak impulse during the interval.

As in the LAS record, the heading calibration is for 180° of azimuth. The binary indicator for heading is a continuous line alongside the azimuth strip. The scriber is moved by a solenoid laterally across the surface, somewhat less than 1/4 inch, to show on-off coding. Along one edge of the medium is a trip-and-date line. This is an event type binary recorder, driven by an encoder that can be manually set to record a succession of six numbers as a series of pulses. The encoder is remote-mounted, usually in the flight compartment.

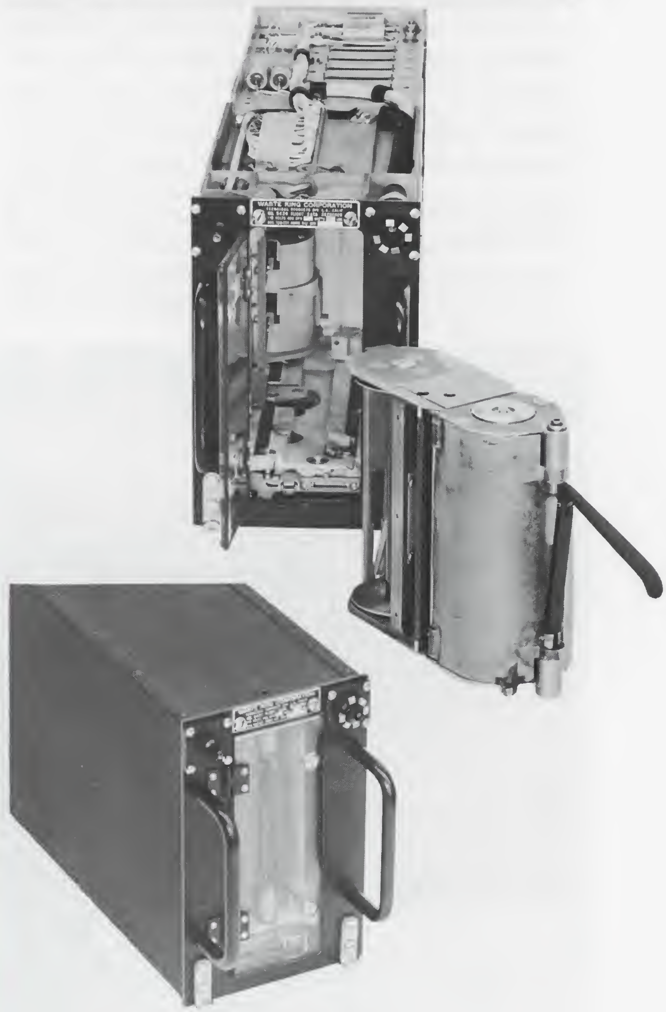
Two other binary scribers are provided for the operator's use. Since a binary record gives only a "yes" or "no" answer, these records are most useful for showing the length of time a certain condition holds. For example, if tied in with a cabin air pressure transducer, the binary line could record precisely how long the pressure remains at sea level; but recording of the actual pressure would be limited to sampling at intervals. In computer language, recording is at the rate of

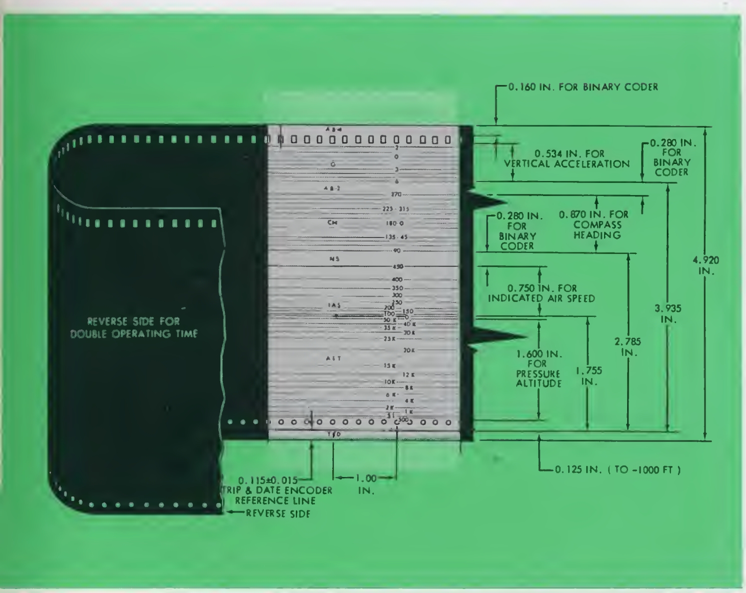


only one bit per half second; recording a pressure would require converting the analog quantity to digital, encoding it, and then recording the code, probably over a time period of several minutes.

The evident advantage of the oscillographic record is that it is visible, immediately available, and storable as is, for as long as desired. The record has such a fine degree of accuracy that machinists' microscopes or projection devices are needed for the best readings possible.

By comparison, tape recorders have two disadvantages: 1) it is more difficult to preserve the record intact in a crash, and 2) the tape must be "played back" in some manner over special equipment for interpretation. On the other hand, tape recorders have potentialities for elaboration of the record. The advantages are that the speed of recording is subject to electrical limitations rather than mechanical — that is, measurable in milliseconds rather than seconds; that a great deal of data can be recorded on small physical areas; and that the information, being already in electrical form, can be fed directly to electro-mechanical and electronic computers and data processors.





Waste King record is on coated steel foil. Main unit, right, is sized for standard shelf mounting.

A brief description of the AG-8 flight performance recorder, now being offered by Minneapolis-Honeywell Regulator Co., will serve to illustrate the speed of recording and the elaboration of the record. In this installation, electronic circuits, heading synchro, time clock, and pressure transducers are in one package, and the recording heads and tape in another. Both units are ATR-sized for electronic compartment mounting. The tape unit has shock and thermal protective materials. The vertical acceleration sensor is remotely mounted near airplane CG.

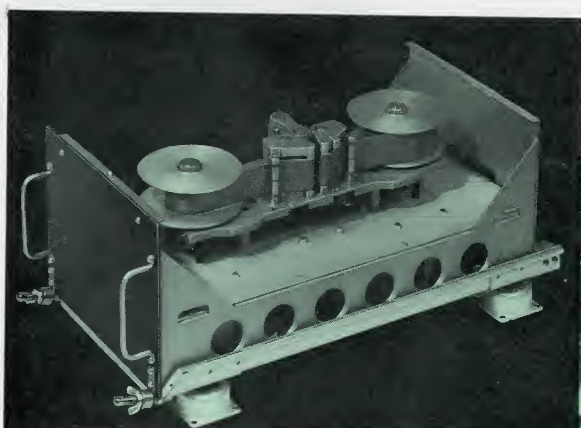
The tape record is digital, in pulse-train form. Number of pulses is directly proportional to input signal amplitude. If reproduced graphically, the pulse train would resemble that of the event-type binary previously described; but, where a scriber may require minutes to record a train of pulses legibly, the tape can record many each second. The transducer signals are fed to an analog-to-digital converter, and thence through comparators and gates to the recording heads. Each of the four parameters is sampled once a second and recorded on a separate channel. Another channel records audio signals. The air crew can address the recorder to identify date and flight number, and also to add data, at any time, about flight plans or unusual flight conditions. This channel is also intended to be tied in with the flight deck warning circuits, to record alarms in audio tone signals. Recording time on the spool is 150 hours; the recording can then be erased and the tape used again.

Another channel is available for operations analysis. On this, data can be multiplexed. Using the same one-second recording time, as many as 60 different readings can be taken once a minute and recorded sequentially. This one channel can add a very large expansion of function for the recorder.

From the operator's view, the information most often desired is that relating to operating procedures and wear and fatigue factors. Engine tail pipe temperature, rpm, and pressure ratio are typical of the useful parameters. Vibration pickups on engines and control surfaces may yield useful data. System pressures and temperatures — hydraulic, fuel, lubrication, air conditioning — can be monitored. Even strain gages can be monitored, if desired.

The data can be read out in several ways. The digital signals can be reconverted to analog and fed to an instrument panel comparable to that on the airplane, or used to operate an oscillographic recorder. The signals can be fed directly, without reconversion to analog, into standard digital counters which print out records in tabular form. They can also be fed to a computer translator for digital computer processing. For making permanent records, either on tape or graph, the tapes can be edited to take out the long-term steady-state portions of the flight that are of no particular interest.

Even more versatile tape recorders are coming on the market. Some record frequency modulation rather than pulse trains, thereby greatly increasing the analog capacity of a single magnetic track. Highly sophisticated recorders and associated ground processing systems are presently being utilized in flight test programs and missile telemetry. The next few years will probably see more commercial adaptations of such systems to monitor flights for guidance in maintenance.



Tape in Minneapolis-Honeywell unit, above, is fed from another unit containing sensors, clock, and synchro.

One method of readout is by making oscillographic record (right). Tape may be fed directly into computers.

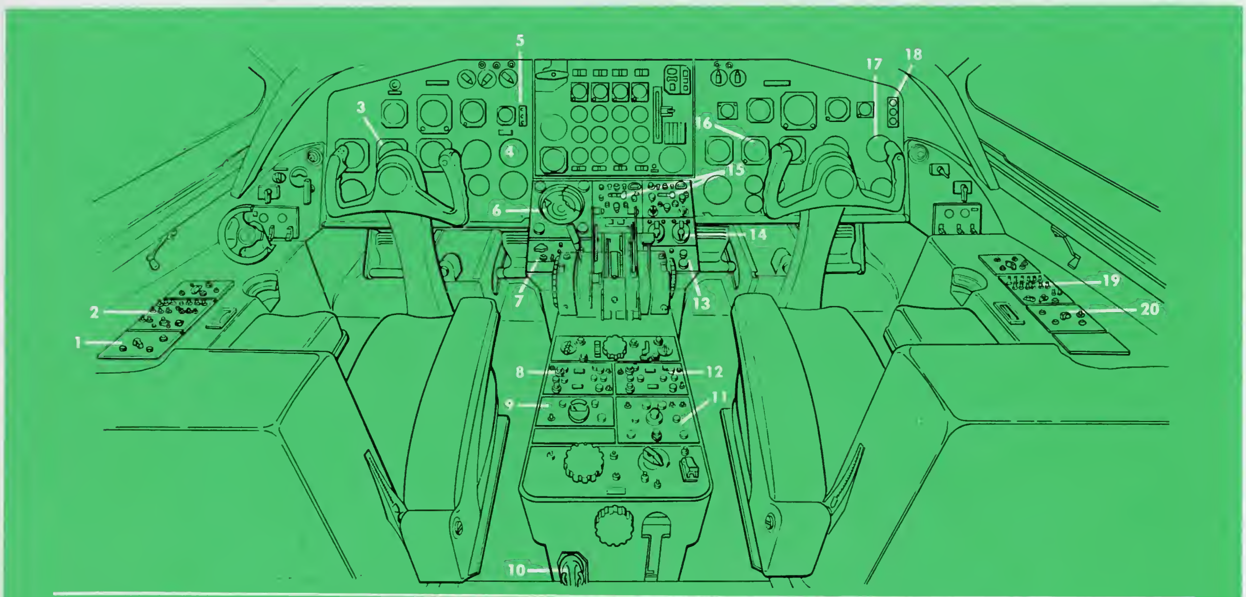
Radio Navigation and Communications, Airplane Intercommunication System

The typical Convair 880/990 jet airliners will begin route operations with approximately eleven radio receivers and three voice transmitters. Each will also have at least one complete weather radar; one receiver-transmitter, to answer automatically-coded queries from the ground; one transmitter-receiver, to interrogate a ground transponder and interpret the reply in miles of distance; and a full public-address and interphone system. Besides these, certain aircraft will have a calling device, to "ring up" the crew from the ground; a long-range navigation receiver to pinpoint positions in mid-ocean; more radar sets to measure ground speed, drift angle, altitude, or to warn of terrain obstacles; a tape reproducer to play music to the passengers; and more spare receivers and transmitters, in case the others fail. If these latter are not in the airplane, the space is there for them, sometimes with antennas, wiring, and connections, so that the units may be merely set in place and hooked up.

This impressive roster of equipment is not, of course, a literal necessity for flight. As far as the airplane is concerned, any competent pilot could fly an "880" or "990" across the continent in halfway decent weather without ever turning on a radio. But that is just not done — not in a commercial transport in 1960. With this equipment in use, the pilot has at his command not only a wide assortment of radio azimuth-finding and piloting aids, but the backing of vast airways systems—national and worldwide—designed to help him find his way and to land safely, at any hour of day or night, in almost any kind of weather.

The basic units that are installed in all "880" and "990" aircraft make available all the ground facilities of the Federal airways. It may occur to some to wonder why basic equipment must include, for example, a dozen receivers (although some are duplicates) to fly radio ranges. The answer lies in the patterns of the navigational networks that have grown up over the past thirty years, changing rapidly since World War II and still changing today.

At the risk of boring some readers already familiar with the patterns, this description will review them briefly in considering the Convair jet airliner navigation and communications electronic equipment.



1 Microphone switch panel
2 Audio selector panel
3 Pictorial deviation indicator
4 Radio magnetic indicator
5 Marker beacon indicator
6 Radar indicator
7 Radar control panel
8 VHF radio No. 1 control panel
9 Public address control panel
10 Public address handset
11 ATC & marker beacon control panel
12 VHF radio No. 2 control panel
13 Selcal control panel
14 HF communications panel
15 ADF control panels
16 Pictorial deviation indicator
17 Radio magnetic indicator
18 Marker beacon indicator
19 Audio selector panel
20 Microphone switch panel

Flight compartment (typical) showing locations of radio and radar equipment.

RADIO NAVIGATION EQUIPMENT

ADF, VHF, Glide Slope, Marker Beacon, DMET, LORAN

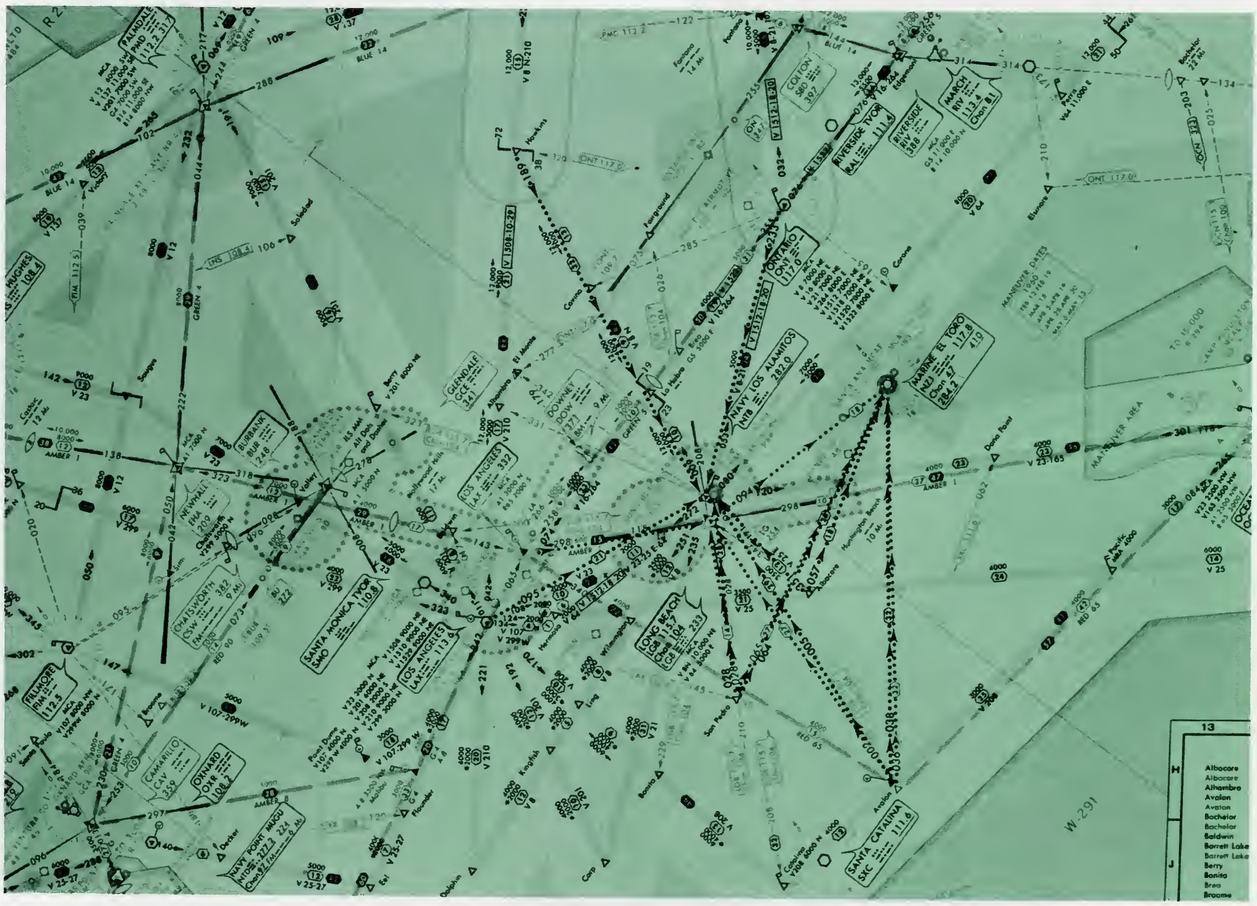
Five basic types of receivers in the airplane will be used solely for navigation, to utilize the airway navigation facilities. These are extensive. On standard aeronautical charts, even skeletal radio data crowds the map areas around major airports. Separate radio guides and charts are a necessity. Airports may utilize up to 20 or more frequency channels, from low to ultra-high. As of last July, more than 60 civil airports had radar-controlled GCA (ground-controlled approach) systems; twice as many had ILS (instrument landing system) facilities.

Airways have been marked since the early 1930's with low-frequency directional radio beams. This network, though still existing today, is all but supplanted for commercial use by a very-high-frequency (VHF) omnirange radio network, and will soon be discontinued altogether.

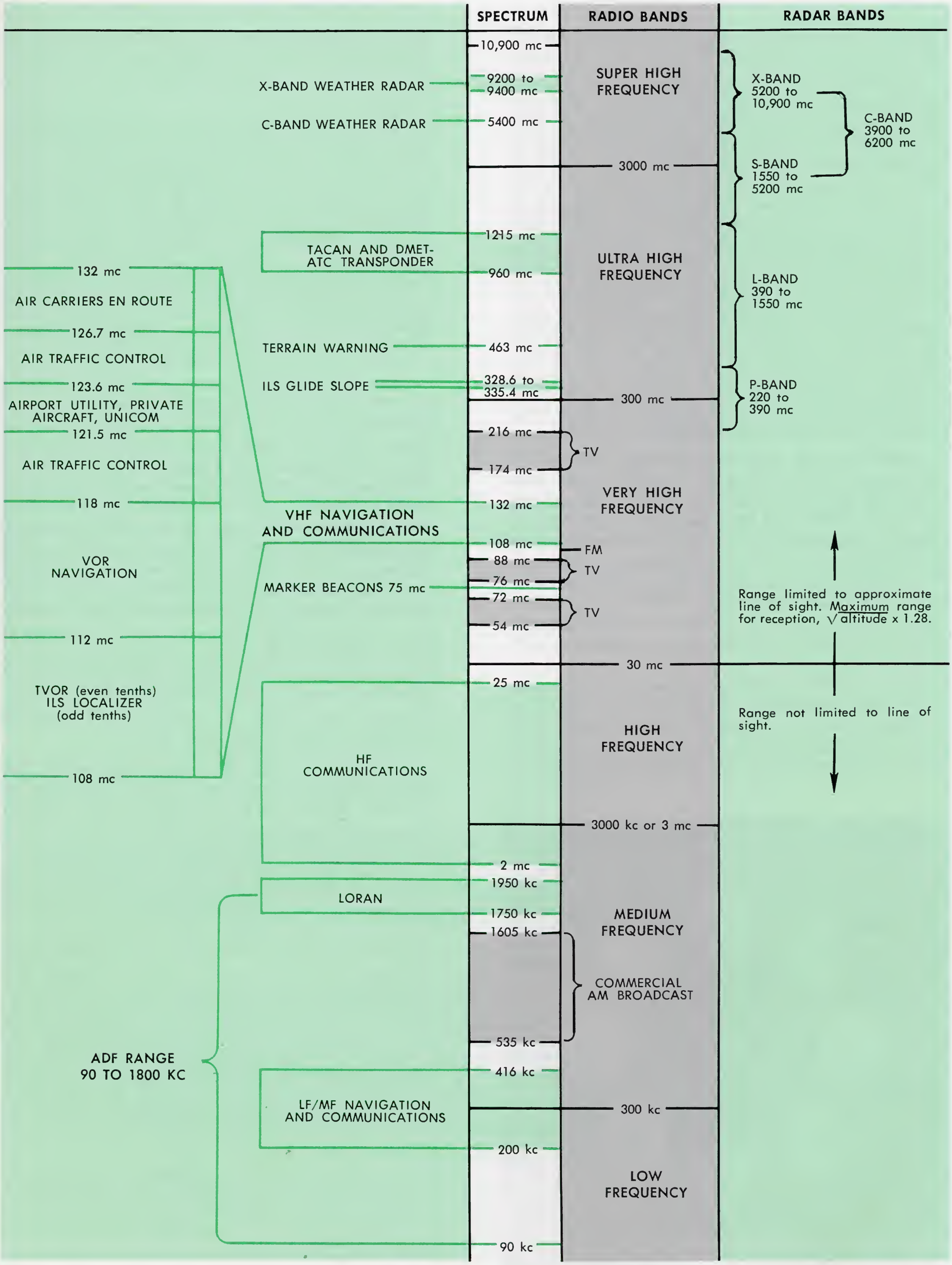
The pilot of an "880" or "990" airplane can still fly by the low-frequency four-course A-N quadrant signals familiar to a generation of flyers; or, more probably, by using these signals to operate his radio compass. This system is known as automatic direction finding (ADF) and, under optimum conditions, may be operable over a range of several hundred miles. In its earliest form, dating back to World War I, the receiver had a loop antenna, linked to an azimuth card; the signal would come in strongest when the plane of the loop pointed toward the broadcast station, weakest when the loop was at right angles to the station direction.

The contemporary ADF receiver still uses such a loop. On the "880," it is mounted in the bottom of the fuselage; on the "990," it is mounted in the top. By a switch on the flight compartment control panel, the operator can rotate the antenna to an aural null. The usual mode of operation, however, utilizes a second non-directional sense antenna on top of the fuselage, comparing the non-directional signal with the directional one from the loop so as to position the loop automatically. Bearing of the broadcast station is transmitted by servos to radio magnetic indicators (RMI's) on the pilot's panels. Each RMI has a compass-controlled azimuth card with two pointer needles. There are two ADF receivers; each may control one needle. Two stations can be turned in at once, establishing two lines of position by the RMI needles.

Frequency range of ADF is 90 to 1800 kc. In addition to the airway range stations, this range includes



Excerpt from radio navigation chart of Los Angeles area.



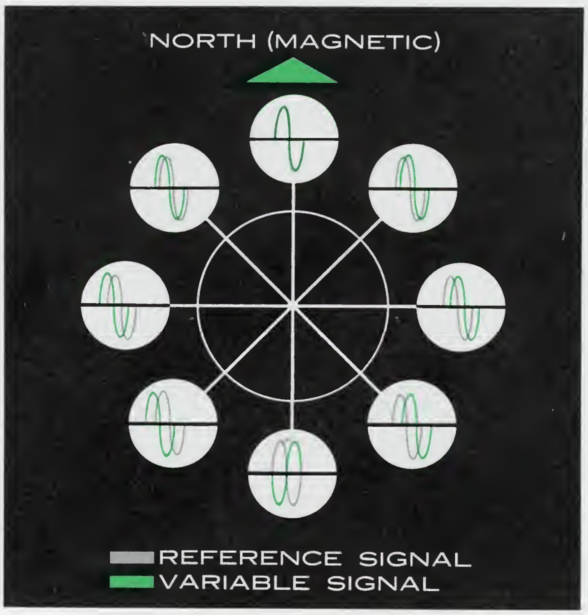
RADIO AND RADAR FREQUENCY SPECTRUM

standard AM broadcast bands, often used by pilots in the early days — particularly if the music was good.

ADF radio today has two limitations, one inherent and one arising from recent technological advances. First, low-frequency reception is subject to external static interference; the automatic direction finder on occasion can be merely an inefficient thunderstorm finder. Second, today's airborne equipment has, as far as possible, eliminated vacuum tubes. The silicon diodes used in transformer-rectifier and other electrical equipment are miniature low-frequency broadcasting units. The resultant interference from inside the airplane has, for practical purposes, proved impossible to eliminate completely, and the effective range of ADF has dropped accordingly in the new jet transports. Convair engineering has been able to filter out an unusual amount of the noise, but the consensus is that ADF will probably never be as efficient in new aircraft as it was when vacuum tubes were more common in the electronic equipment.

ADF, however, is of secondary importance to the jet airplane. Most civilian high-speed aircraft, when following major air routes by radio, navigate almost entirely by VHF (very high frequency) radio. The frequencies are from 108 to 117.9 megacycles, where static interference is far less. Reception is limited to line-of-sight distance — at 35,000 feet altitude, 175 to 200 miles. Today, continental United States is well blanketed by omnirange facilities, and aircraft on the principal airways are never outside range of a VHF station.

There are two omnirange systems in current use, VOR (VHF Omnidirectional Range) and ultra-high-frequency TACAN (TACtical Air Navigation), the latter principally military for direction-finding purposes. Both broadcast two signals simultaneously, one a reference signal and the other variable. The signals are beamed in all directions (hence "omni") but provide a directional signal for the airborne receiver.



VOR 30-CYCLE WAVE PATTERNS

The VOR receiver measures a phase difference between the two radio signals. The reference signal, transmitted by FM on a frequency between 112 and 118 mc, is modulated to 30 cycles per second with a constant phase in all directions; the variable signal, transmitted by AM, is also 30-cycle, and is in phase with the reference signal along the magnetic north beam, but out of phase in other directions, depending on the direction of the receiver from the transmitter. The receiver compares the two phase signals; the difference in phase is interpreted into an instrument reading of the bearing of the transmitter.

There are two VOR receivers on each Convair 880 and 990 Output of the receiver formerly was to an omnibearing indicator (OBI). For instrument purposes, "880" and "990" aircraft, though they may still have an OBI, make principal use of the VOR signal in RMI's and/or deviation indicators on the pilot's panels. There are several types of instrument systems available. In some, the bearing of the VOR station may show on the RMI, with or without simultaneous ADF bearings; or the bearing may show on a compass repeater with a second pair of RMI needles. In all "880" and "990" aircraft, deviation of the airplane from the selected radial of the VOR station will be shown on some indicator — the radial's position and angle relative to airplane heading, whether right or left, and how much right or left. The VHF navigation receiver provides an aural output for station identification and scheduled weather broadcasts.

A number of airports have a short-range low-power terminal omnirange (TVOR) for lining up with the runway during instrument flight letdowns. Most of the country's major airports now have more sophisticated Instrument Landing System facilities.

An ILS transmitter near the runway transmits two highly directional localizer signals side by side, one modulated to 90 cps and the other to 150 cps, on radio frequencies between 108 and 111.9 mc, just below the VOR band. The vertical plane along which the lobes of the two signals overlap is aligned with the runway; the airborne VHF navigation receiver, on ILS frequencies, has circuitry to respond to this pair of signals as in VOR reception, and the deviation indicator will show position and heading of the airplane relative to the localizer beam.

A second element of the ILS system is a glide slope transmitter, which also puts out two overlapping lobes of directional beams, one above the other. The lateral plane of overlap is the glide slope, projected up from the end of the runway at 2.5° to 3° angle. Carrier frequency of the glide slope is between 328.6 and 335.4 mc, in the UHF (ultra-high-frequency) range. Since reception is simultaneous with localizer reception, a separate receiver is required. Tuning the VHF navigation receiver to the localizer frequency automatically tunes the glide slope receiver. Instrumental

output of the glide slope receiver is to the flight instrument system; relative position of the slope is shown by a horizontal bar, displaced from instrument vertical center by an amount proportional to the airplane vertical distance from the glide slope.

VHF navigation and glide slope receivers have a second important function in flight; the autopilot can be placed under their control. In "880" and "990" aircraft, the autopilot will take the airplane to a VOR radial and follow it to the transmitter, over it, and away from it on a reciprocal heading. In ILS autopilot operation, the airplane will automatically find the center of the localizer beam, follow it to the intersection with the glide slope, automatically lock on the glide slope, and follow it down to the runway end.

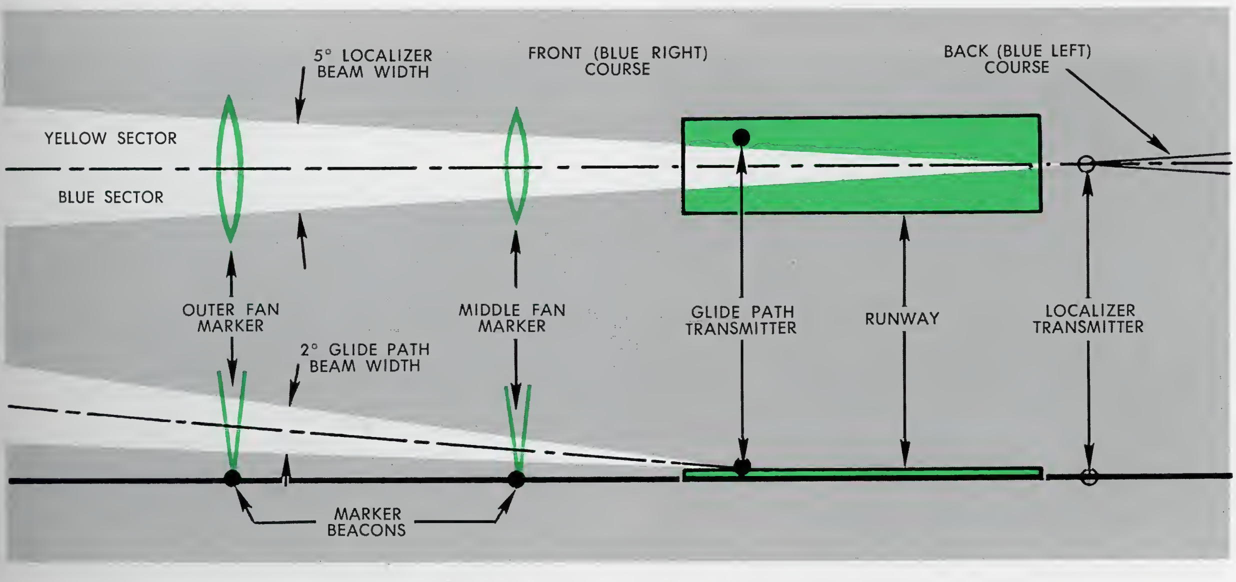
A third element of the ILS system requires still another unit, the marker beacon receiver, permanently tuned to 75 mc. Ground radio beacons transmit a 75-mc modulated signal straight up, in cone, fan, or bone-shaped patterns, to mark certain points. An ILS approach lane will have outer and middle markers at 1- to 15-mile distances; as an airplane passes over one, a momentarily strong signal will be received — modulated with 400 cycles over the outer marker and with 1300 cycles over the middle marker — carrying Morse code identification. Marker beacons also mark enroute points on the airways and the cone of silence over low-frequency range stations; these signals are modulated to 3000 cycles. However, enroute markers are being discontinued along with the low-frequency network.

The tones may be heard in the headsets or flight compartment speakers. On some airplanes, colored lamps on the instrument panels illuminate when the signal is received.

The other omnirange system, TACAN, operates similarly to VOR, except that frequency range is between 962 and 1213 mc. TACAN transmitters are frequently found together with VOR, in ground units identified as VORTAC stations. Since VOR supplies bearing information, this portion of TACAN is not usually utilized by commercial aircraft. TACAN does, however, have an added navigation feature for measuring, with a high degree of accuracy, the distance of a TACAN-equipped airplane from the station. Some VOR stations without full TACAN equipment are supplied with the distance-measuring unit. Most "880" and "990" aircraft will be equipped to take advantage of this facility with DMET (Distance Measuring Equipment — TACAN).

When the VHF navigation receiver is tuned to a VORTAC station, the DMET receiver will automatically be tuned to the associated TACAN frequency. The airborne unit transmits a coded interrogation pulse to the ground unit, in the middle frequencies of the TACAN band (1025 to 1150 mc). The ground unit instantly replies, in the same code, in another frequency in the upper or lower portion of the TACAN band. The airborne receiver electronically measures the time lapse between interrogation and reply, translating this into an electrical signal for instrument use. The distance appears in a digital mileage readout of the DMET output in a small panel instrument. Accuracy should be within a sixth of a mile, or within 0.2% of the total distance. It must be remembered, when the airplane is nearing the transmitter, that the distance shown is not geographical; it is to the transmitter itself. At 30,000 feet directly above the station, for example, the DMET mileage indication will be 5 nautical miles.

Still another navigation unit will be found on some "990" aircraft to be used in overwater flights. It is a long-range navigation receiver for LORAN a system developed during World War II. Since LORAN frequencies are just above standard AM broadcast bands (1750 to 1950 kc), fixes comparable to celestial fixes are obtainable at distances up to 1500 miles from the transmitters.



INSTRUMENT LANDING SYSTEM

LORAN stations are all over the world, most of them especially placed to cover coastal waters. They are in pairs some distance apart, one transmitter being slaved to the other. Both broadcast identical 40-microsecond pulses alternately on the same frequency. By use of a cathode-ray screen, resembling an oscilloscope, the signals are matched and the time delay between the two signals determined. This provides a single line of position based on distance differential, therefore hyperbolic in form rather than straight. A second line of position is obtained from another LORAN station pair; the intersection of the two hyperbolas is the airplane position. Special LORAN charts are required to provide the line-of-position pattern for each station pair.

COMMUNICATIONS

VHF, HF, Selcal, Intercom, PA Systems

The band above VOR, 118 through 132 mc, is used for civilian VHF communication between aircraft or between aircraft and ground. Dual separate receivers, often almost identical with VHF navigation units, are provided for communication, with transmitter units added. Some airlines depend entirely on VHF channels for communication; it is limited to line-of-sight, but ground facilities are entirely adequate for domestic traffic. However, many "880" and "990" aircraft will have, in addition, a high-frequency communication receiver and transmitter, operating on frequencies from 2 to 18.5 mc, or 2 to 25 mc. These frequencies are more subject to weather interference, but the optimum range under good conditions may reach into the thousands of miles. Standard installation usually calls for one HF radio, with provisions for later installation of a second.

A recent addition to air-to-ground communications systems is Selcal (selective calling). It will be installed in a number of Convair jet airliners, and provisions will be made in others not factory-equipped.

The Selcal airborne unit is a "black box" linked to the communications receivers; when triggered by a ground signal, it sounds a chime and illuminates a panel light to let the crew know a call is being received. Once a station is tuned in, the receiver need not be continuously monitored by the crew.

The ground station signal is a pair of consecutive audio tone pulses, each consisting of a pair of pure tones selected from a 12-tone coding system. A flight is assigned a certain sequence of tones, and the airborne unit is preset to this code. The Selcal unit can monitor two channels at once, from either HF or VHF receivers.

Audio output of ADF, VHF, or HF radio can be fed to headsets for the crew, or to a pair of loudspeakers overhead in the flight compartment. Audio selector panels are located on pilot's and copilot's consoles and on the flight engineer's panel, besides one in the electronics compartment. Microphones are provided for the pilots and flight engineer, and for emergency in the smoke and oxygen masks.

The flight compartment microphones and speakers are also usable with the airplane intercommunications system. The intercom is a "party line" system, with handsets at the stewardess stations, and jackboxes at the wheel wells, nacelles, cargo compartments and tail cone. A handset is also located on the aft face of the center pedestal, for contacting cabin stations or for public address system announcements.

The PA system comprises speakers mounted overhead in the cabin, one for each two rows of seats. Announcements may be made from the flight deck or from either stewardess station. Tape reproducers for playing music through the PA speakers are installed in some aircraft; they are located in the electronics compartment and controlled from the forward cabin station. Priority relays give priority to announcements from the flight deck, forward stewardess station, and aft stewardess station in that order.

SELCAL AIRBORNE UNIT

DMET INDICATOR

Weather Radar and other Electronic Equipment and provisions

Airborne weather radar and an Air Traffic Control radio beacon, or transponder, are now required by the Federal Aviation Agency as standard equipment on new transports.

Airborne radar, generally familiar by now, has a transmitter which sends out a narrow beam of short high-intensity pulses from a rotating antenna. Echoes returned from objects in the path of the pulse are sensed by the receiver and translated into a visible indication on a cathode-ray screen, somewhat comparable to a small television screen. Frequency for weather radar is usually in the C-band (5400 mc), sometimes in the X-band (over 9000 mc). The antenna, a dish-shaped reflector mounted in the nose radome, rotates at 15 sweeps per minute. The area scanned covers approximately 240°, the pulses being absorbed when the antenna is turned back upon the airplane itself.

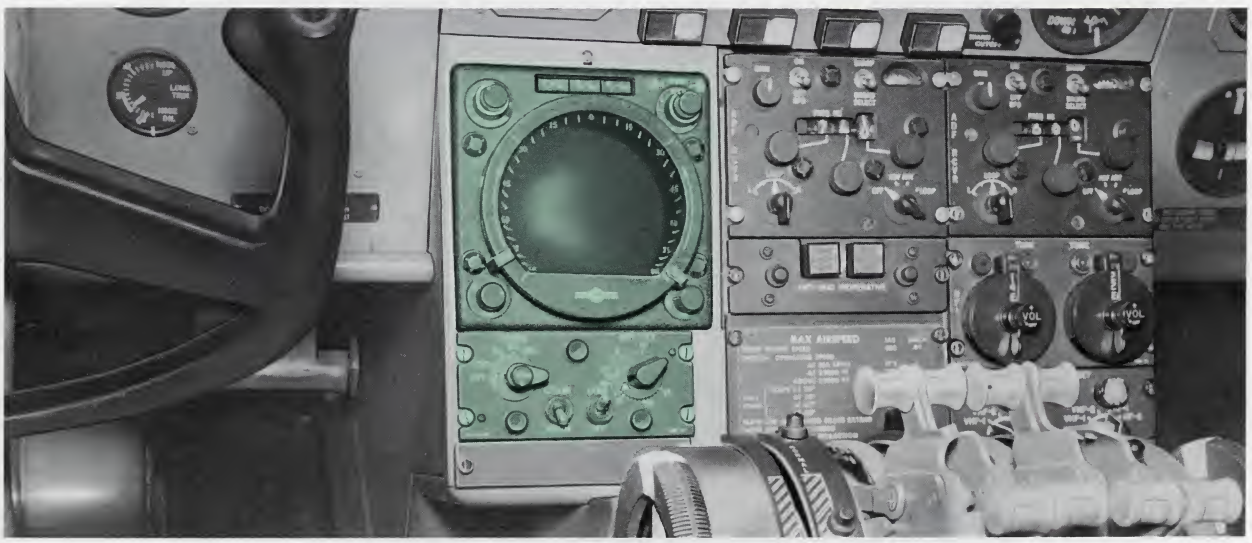
The indicator is a 5-inch screen mounted in the forward pedestal panel. A sweep line rotates with the antenna, causing bright areas to appear on the screen where the signals are echoed. In weather radar, the reflections will come from precipitation in the atmosphere.

The distinguishing feature of weather radar is that the intensity of the echo signal is carefully evaluated to be reflected in the brightness of the screen, so that the brightness is a measure of the density of precipitation. It is "penetration" radar; all the echoes from within a rainstorm will be received, so that the pattern on the screen is a precipitation map of the area covered. Within a twenty-mile range, it can be made to show storm contours and rainfall gradient with a high degree of accuracy. Since precipitation accompanies centers of turbulence in storm fronts, the weather radar has proved the most effective means ever devised for avoiding rough air with a minimal amount of detouring.

Radar weather displays, and the use of the radar for ground mapping, will be more fully described in a future issue of the Traveler.

The Air Traffic Control transponder operates in conjunction with ground radar. Airport radar is of two types: airport surveillance radar (ASR), with a 30- to 60-mile range; and precision approach radar (PAR), with a range up to 10 miles. ASR provides range and azimuth of aircraft; PAR also supplies aircraft altitude, so that airplane position can be accurately established during final approach. The operator talks to the airplane via ordinary communications radio. With PAR ground-controlled approach, an airplane can be kept on the glide path in bad weather down to the very end of the runway.

What the ATC transponder supplies is an aid to the ASR radar, as well as a coded message-bearing signal. An interrogator, coupled to the ASR transmitter, transmits a pair of pulses 8 microseconds apart on a 1030-mc frequency; the airplane replies on 1090 mc with a group of up to 8 pulses spaced to make a coded reply. The code can be set by the pilot to convey certain information — whether he is landing or enroute, or to convey other such data as may be set up in standard codes, of which 64 are available. By actuating a switch on the control panel, the pilot may add another signal for identification purposes.



Weather radar screen and control panel are on pilot's side of center console. To the right are two ADF radio panels, HF communications radio tuning controls, and Selcal control panel.

Radiating beam of terrain warning radar is fanshaped, sweeping approximately 170° forward, down, and aft.

Besides the coded messages, the transponder signal reinforces the ground radar echo signal, thereby considerably extending surveillance radar range. If the airplane already shows on the radar screen, the "blip" will grow in size and brilliance when the airplane is interrogated. This makes it possible to track an airplane more accurately through weather interference or ground clutter.

A terrain warning radar, with short range, operating on comparatively low frequency, will be found on one version of the "880". This directs a 463-mc radar beam down and ahead of the airplane; if it encounters an obstruction within the range chosen, a warning light flashes and a gong sounds. The range may be selected at 500, 1000, or 2000 feet.

At least one airline has announced its intention of installing Doppler system radar in the Convair 990; provisions or space for it are in all models. This is a piloting aid that provides an accurate ground speed reading on a digital counter, together with an indication of wind drift angle in degrees.

Doppler radar depends on a phenomenon known to physicists for a century as the Doppler shift, the apparent change in frequency of a wave succession between two bodies in motion relative to each other. A ship at sea crosses more waves against the wind than with it; pitch of a locomotive whistle drops perceptibly as it passes an observer. In Doppler radar, reflected radio-frequency waves from a beam directed toward the ground ahead of an airplane return at a higher frequency than do those from a beam slanted down to the rear.

Although the number of waves per second is in billions (frequency is approximately 8800 mc), the difference between the beam frequencies is measurable electronically, and can be utilized to drive an indicator counter. In most aircraft installations, two beams are directed forward, one toward each side, and two aft. A pulse is projected simultaneously along left-forward and right-aft legs, then along right-forward and left-aft legs. The differences can be separated into components representing rate of forward motion and rate of side drift.

Doppler radar directs multiple beams forward, aft, and to each side, to sense ground speed and drift.

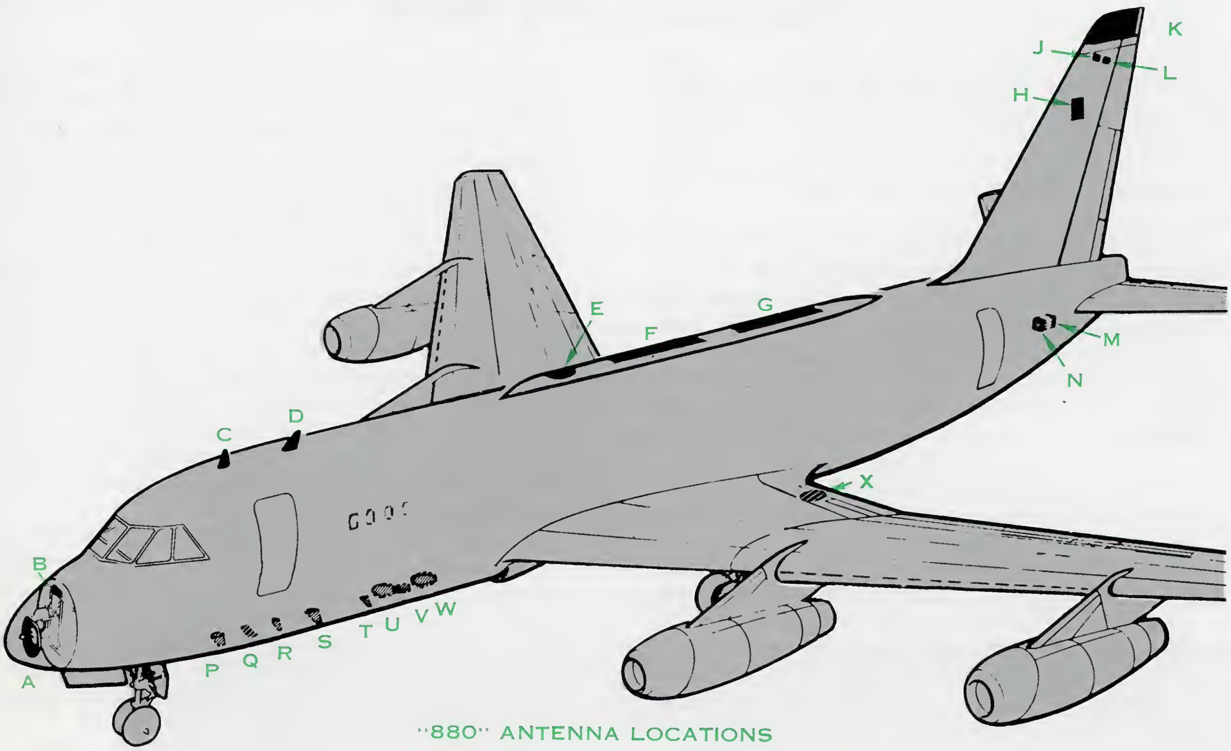
The great advantage of Doppler navigation is that it is completely independent of weather and ground-based aids. Dead-reckoning navigation becomes almost an exact science. Drift and ground speed are measured continuously anywhere in the world; speed accuracy is within 3 knots ± 0.6% of the total reading, drift angle within ½°. The installation is comparatively new, but the number in use is growing.

Space provisions have been requested in some aircraft for proximity warning radar and radar altimeters. The one will warn of the near presence of other aircraft; the other will supply a height above ground, rather than barometric altitude with respect to sea level.

System Components

The VHF communication, VHF navigation, ADF, glide slope, and DMET units are all dual installations, with separate receivers, transmitters, control panels, and (except for VHF navigation and glide slope receivers) separate antennas. All HF and VHF equipment has crystal-controlled step tuning. One of each pair of units is accessible to the pilot, the other to the copilot. Should the pilot's navigation radio equipment fail, he can switch his instruments and the autopilot to the copilot's VHF and glide slope receivers. The major part of the radio and radar equipment is in an electrical and electronics compartment, just under and aft of the flight deck. The compartment is accessible in flight through a door in the floor of the forward coat closet.

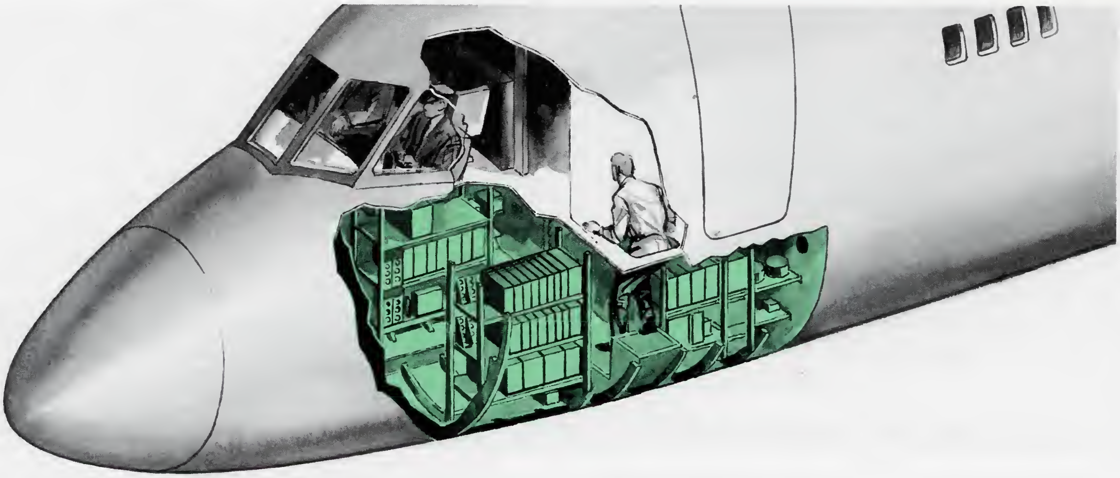
Antennas are located in the vertical fin (HF communications, LORAN, and VHF navigation); along the dorsal centerline of the fuselage (ADF sense, DMET, VHF communication and, in some aircraft, ADF loop); in the radome (weather radar and glide slope); and at the bottom of the fuselage (ADF loop, DMET, marker beacon, VHF communication, Doppler radar). Some antennas are flush-mounted in fiberglas, some are blade type. Couplers and antenna tuners are mounted near the antennas.



"880" ANTENNA LOCATIONS

A	WEATHER RADAR	M	NO. 2 COUPLER CONTROL*
B	GLIDE PATH	N	NO. 1 COUPLER CONTROL
C	NO. 2 DMET*	P	NO. 1 DMET
D	NO. 3 VHF COMMUNICATIONS*	Q	TERRAIN WARNING
E	NO. 2 VHF COMMUNICATIONS	R	NO. 1 ATC TRANSPONDER
F	NO. 1 ADF SENSE	S	NO. 1 VHF COMMUNICATIONS
G	NO. 2 ADF SENSE	T	NO. 2 ATC TRANSPONDER*
H	VHF NAVIGATION	U	NO. 1 ADF LOOP
J	NO. 1 HF COUPLER	V	MARKER BEACON
K	HF COMMUNICATIONS	W	NO. 2 ADF LOOP
L	NO. 2 HF COUPLER*	X	DOPPLER RADAR*

*PROVISIONS ONLY



Electrical and electronics compartment houses racks of "black boxes," with room for more when needed. In-flight access is through floor plate in forward coat closet.

Providing for the Future

Contemplation of this array of electronic equipment, with controls all concentrated in one compact-as-possible flight compartment, leads to a suspicion that a saturation point is rapidly approaching. The airplane may hold more, but there won't be enough crew to man it.

This factor is recognized by the commercial and Federal agencies concerned. However, the present pattern of the airways system is nearing a goal set some years ago; not that airway facilities will cease to change, but that there should be a relative stability for a certain length of time. The basic electronic configuration of the Convair 880 and 990 aircraft will probably continue to satisfy all essential requirements for some years to come, perhaps through the 1960's.

There is one exception: one system, still in process of development, is expected to be ready for use in the forseeable future, perhaps by 1962. It is presently designated AGACS (pronounced Ajax), standing for Automatic Ground-Air Communications System, and it is regarded as today's most pressing development program involving airborne electronic components.

It is well known that airports daily become more crowded — complex radar-computer units are being installed, some experimentally, in large airports to keep track of arriving and departing aircraft. Ground radio control rooms reflect the rush of airway business by becoming overloaded with communications. Even with multiple channels and crews to man them, there is sometimes more talking to do than there is time.

It is believed that a relatively compact airborne unit, together with corresponding ground facilities, can relieve the congestion of communication radio channels. A sizable proportion of air-ground communication is concerned with enroute flying, rather than with airport takeoff and landing. It consists of requests, or instructions, for altitude or route changes, weather reports, flight clearances, and the like; and routine reporting of position, altitude, and flight plan estimates. On our airways today, every commercial and military flight is monitored from the ground from takeoff until landing. The enroute data must be recorded, evaluated, and often passed on to other facilities. Even so, there is constant pressure to keep even closer track of what is flying and exactly where.

AGACS proposes to set up a coded signal system to remove the routine transmission of data from voice channels. Currently, the program is in proposal and research stage only. It has been established, however, that a ground station using only one channel could record flight altitude, for example, of 500 aircraft every two minutes. In one proposal, 32 coded messages would be available for reports and inquiries between airplane and ground, any of which could be transmitted within 24 milliseconds.

Another system, developed and proposed by Stromberg-Carlson, a division of General Dynamics, would transmit preselected messages at only 1/15th the rate per bit, but would permit simultaneous voice and data transmission, and could also be tied in directly with teletype circuits. Whatever the final choice, AGACS equipment would be made compatible with ground computer and relaying systems.

The plan is to utilize VHF and lower UHF frequencies. It may be possible to use transceivers already in the airplane, with additional units for computing, encoding and decoding, and for making the information available. However, just what equipment will be required, and how much information will be exchanged, has not yet been settled.

Under the circumstances, the only provision for AGACS that could be made in the Convair 880 and 990 was to leave space for it. This is available. Even with the dozen and more radio units, LORAN, weather and Doppler radar, and other assorted installations already in the airplane, there will still be space for more if or when it is required.

Weather Radar in the Convair 880/990

RADAR, which stands for RAdio Detection And Ranging, was developed during World War II for military use. Placed aboard service aircraft, this new device, with its ability to "see in the dark," proved to be much more versatile than its designers had anticipated. Initially designed to be operated as a navigational and bombing aid, radar scored a hit by becoming adaptable to a variety of other uses including weather surveillance. Radar operators quickly discovered that, with a little practice, they could identify storms on their radar scopes and steer clear of such disturbances.

Proving its worth during many thousands of flight hours in the hands of military fliers, radar was ready to be adapted to civilian use at the close of the war. The system, designed as weather radar, was installed in commercial airliners for the primary purpose of indicating storms and atmospheric disturbances. Commercial radar enables pilots and navigators to pick out smooth paths through storm fronts and turbulent areas.

The Convair 880/990 jet airliners are equipped with the most modern weather radar systems available. With the experience gained through the installation of radar sets in the Convair-Liner 440, Convair was able to design the radar installation in the 880/990 for ease of access, serviceability, and optimum results. Particular radar systems are installed on the 880/990 according to customer requirements.

Radar is based on the principle that high frequency radio waves, like light, will reflect from an object caught in its path. The radar signals are transmitted as high power pulses that reach the object (target) in a straight line, after which part of the signals are reflected back to the transmitting source. These reflected signals are converted into visual indications and are viewed in the cockpit on a cathode-ray tube indicator, or scope.

The length of time it takes the radar signals to reach the target and return is accurately measured electronically to furnish range. Azimuth information is obtained through the action of the radar antenna which rotates through 360° — transmitting and receiving signals in a narrow beam, comparable to that of a spotlight.

Continuing post-war development has perfected a feature known as iso-echo contours, a refined scope presentation that enables a pilot to determine quickly and accurately the position, intensity, and extent of storm cells. The reliability of this system permits the pilot to pick a route through a storm area within four miles of its turbulent centers, thereby minimizing detours and delays.

As the intensity of the weather radar return signal depends on the concentration of water particles in the path of its beam, and the turbulence of a storm is proportional to its rainfall gradient, usual conditions indicate that the brighter the return, the worse the storm. But, during some conditions, the face of the radar scope will show an indistinguishable return, as when radar-reflecting particles are prevalent in the area of sweep. In such cases, the iso-echo contour feature of the radar system is brought into play.

This iso-echo contour feature of the weather radar system permits positive identification of storm areas and accurate positioning of the turbulent cells, regardless of the contrast nature of the picture. When the rainfall gradient reaches a certain level, the screen goes black in those areas. The resultant picture shows characteristic black "holes" ringed by light areas. By avoiding the black areas which indicate high turbulence, the pilot can continue on course along a relatively smooth flight path.

Iso-echo contour feature of 880/990 weather radar presents smooth flight path between storm centers.

Radar antenna, rotating 360° at 15 rpm during operation, is located in plastic radome nose.

This feature has proved to be economically advantageous because it makes possible the prevention of long and costly detours around storm centers, and permits much smoother flights for passengers.

Weather radar, as installed in the Convair 880/990 jet airliners, is designed to offer the additional feature of terrain mapping. With the antenna beamed slightly downward, this navigational aid makes possible the identification of coastlines, rivers, cities, and other prominent landmarks.

Another feature of the versatile radar system is its ability to indicate absolute altitude above the ground by use of the altitude circle. A small amount of radiated energy constantly escapes from the normal pattern of the radar beam and strikes the ground vertically. The reflected target appears on the radar scope as a circle, caused by the rotation of the antenna. With the range marker set on the 20-mile range, absolute altitude is determined by estimating the distance from the sweep center to the inside of the altitude circle.

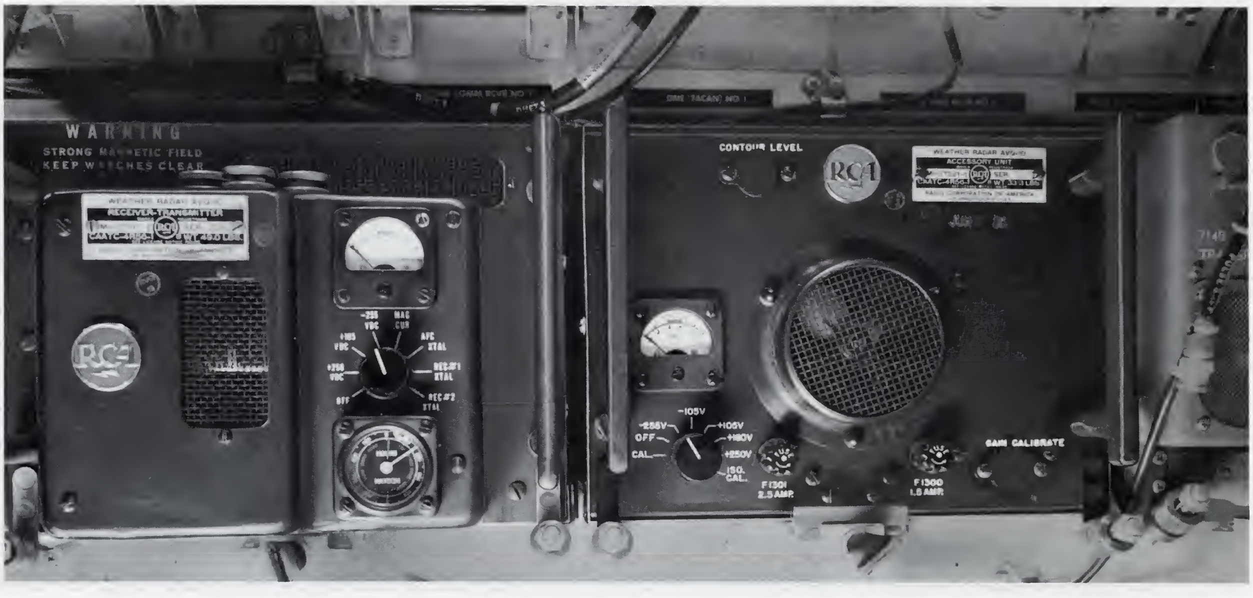
The weather radar system installed in the Convair 880/990 jet airliners is either in the C band or the X band, depending on customer requirements. The C-band equipment operates on a wavelength of 5.7 centimeters and has a frequency of 5250 to 5440 megacycles. The X band has a wavelength of 3 centimeters and represents a frequency of 9200 to 9400 megacycles.

The weather radar system consists of five units: the receiver-transmitter, the synchronizer unit, the antenna, the indicator, and the control panel.

The receiver-transmitter unit is located in the radio compartment beneath the flight deck in the left-hand equipment rack. It contains the basic electronic circuitry (RF and IF) for the transmission of signals to the antenna and for receiving the signals reflected back to the antenna. These reflections are translated by the receiver into the visual indications — light areas of varying intensity — displayed on the cathode-ray tube indicator.

The synchronizer unit contains the power supply, the basic timing circiutry, and the servo amplifiers, which amplify the voltages used to synchronize the indicator sweep traces with the rotation of the antenna. It also provides voltages of proper amplitude and phase for horizontal stabilization of the antenna. The synchronizer unit, also located in the radio equip-

Receiver-transmitter at left and synchronizer unit at right are two of the five units of radar system.



ment compartment, is installed at the right side of the receiver-transmitter unit.

The radar antenna radiates radar energy and receives the portion that is reflected back from the target. It is of parabolic "dish" shape and rotates continuously through 360 degrees at a rate of 15 revolutions per minute. The antenna assembly provides vertical tilt and stabilization of the antenna against roll and pitch of the aircraft.

The radar antenna is located within the radome in the nose of the 880/990. The radome is hinged at the top and can be swung open for access to the antenna assembly. The radome is held in the open position by hold-open supports on each side.

The indicator, known as the Plan Position Indicator (PPI), is basically a cathode-ray tube that converts the reflected radar energy received by the antenna into the visual indications of light and dark areas visible on the face of the tube. Indicator adjustments control the brightness of the indicator sweep to bring out the best "picture" on the tube, and control the lighting of the indicator panel. Some indicators have cursor lines, scribed on the face, that may be rotated for an azimuth fix on a target. CONTOUR and RANGE controls are also mounted on some indicators.

The indicator is located just below the engine instrument panel, on the pilot's side, directly in front of the control pedestal.

The radar control panel contains all of the system controls with the exception of those on the indicator. There is the OFF-STANDBY-ON switch for turning on the set, the GAIN control that adjusts the sensitivity of the receiver, and the TILT control that moves the antenna reflector up or down to direct the radiated beam to the desired angle. The RANGE control, either on the indicator or on the panel, selects the desired range markers (20, 50, 150 nautical miles) and adjusts the light intensity of the marker rings. The CONTOUR switch on the panel or on the indicator activates the iso-echo contour function of the set for more accurate determination of storm cells.

The radar control panel is located on the panel just below the engine instrument panel. It is positioned directly below the indicator.

Microwave-absorbing material is installed on the bulkhead behind the radar antenna to protect radar receiver circuitry.

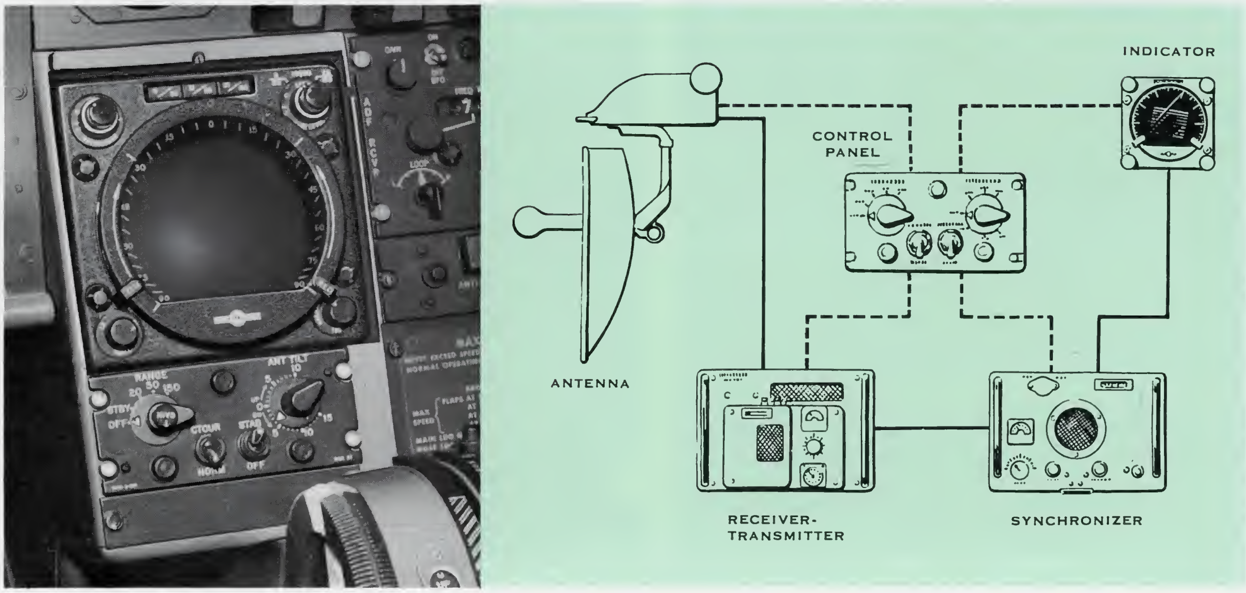
To eliminate the possibility of injury to personnel, no one should be exposed to a direct radar beam where the power density is above the maximum allowable of 0.01 watt per square centimeter. No person should be exposed to unattenuated radar beams within 75 feet of a radiating antenna.

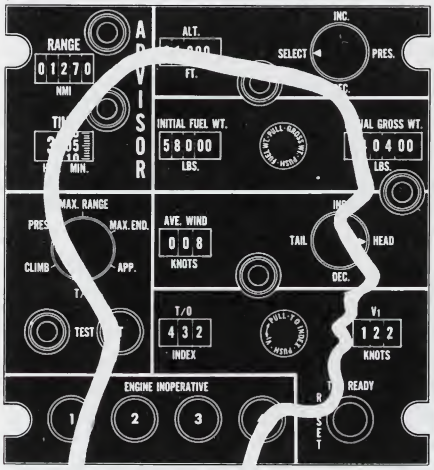
In field testing, the radar beam should be directed as high above the horizontal as is practical. Before operating radar equipment, the affected area should be posted with signs and flasher lights, and should be supervised to preclude the possibility of exposure to the radar beam.

To prevent possible damage to the radar equipment, the set should not be operated while the aircraft is in an enclosure, or with the antenna directed toward large metal objects close at hand. The system should never be operated during fueling operations or in proximity to fuel containers.

Unshielded electric primer caps, squibs, other explosives, and even photo flash bulbs are capable of being detonated by microwaves, and should not be stored or transported within the area around an energized radar set.

Weather radar indicator (scope) and control panel are at right of pilot, below engine instrument panel.





ADVISOR

ADVanced Integrated Safety and Optimizing computeR

In the flight compartments of each of two Convair 880 test aircraft, on the console to the right of the copilot, is a small panel containing several digital counters and adjustment knobs. Unobtrusive as it appears, this panel may make more difference in the navigator's chore in commercial transports than any other one of the manifold aids to navigation.

The device is ADVISOR, a combined takeoff monitor and in-flight computer. Convair Flight Test Engineering and the John Oster Manufacturing Co. are cooperating in developing and testing the first ADVISOR adapted for commercial transports. Convair has no proprietary interest in the device; the primary consideration is to help solve some operational problems that are becoming acute in the jet age.

Flying a mile every six or seven seconds, burning a barrel of JP-4 every couple of minutes, a jet transport is hard to keep up with, in more ways than one. "Stop to light a cigarette," a harried jet flight engineer told a reporter last year, "and you may lose track of a thousand gallons of fuel." Planning and re-planning a flight is the busiest job on the flight deck.

ADVISOR (ADVanced Integrated Safety and Optimizing ComputeR) is designed to present the following information:

1. Required airspeed buildup during takeoff ground run-up to V_1 velocity (refusal speed, beyond which the airplane is committed to take off).
2. Airspeed for best climb; for maximum range or maximum endurance at present altitude, or at any selected altitude; or optimum speed for final approach.
3. Range remaining at present speed and altitude, or maximum range at any selected altitude.
4. Time remaining at present speed and altitude, or with maximum range setting at other selected altitudes; or maximum endurance time at any selected altitude.
5. Range and time figures in engine-out operation.

Already proved in a jet bomber flight test program, ADVISOR is being installed in a class of military turboprop transports. With Convair's aid, it is being adapted for "880" and "990" jet airliners.

Convair pilots and engineers believe that the development of such a computer is inevitable. Flight planners and navigators have better instruments and more facilities available every day; but, the plain fact is that, while navigation is far more exact than during World War II, for example, it is also more exacting; the time required for the job hasn't lessened.

The B-25 "bombigator," without having to "fiddle" with LORAN squiggles or VORTAC radio and radar beams, was still never bored on long missions. He was too busy plotting wind vectors, thumbing through his files of charts and nomographs, and "working cruise control"—running endless problems of how far and how high he could travel on how much fuel. His tools were his flight handbook, Weems plotter, and E-6B circular slide rule.

That part of the job hasn't changed. At this minute, there are pilots and navigators all over the world leafing through their papers for the proper fuel consumption graph and twirling their card computers to estimate fuel weight on arrival and possible alternate flight plans. If the airplane involved is a jet transport, there isn't much time, and the navigator's answer had better be correct; by the time he rechecks, he's somewhere else.

ADVISOR, in addition to aiding the pilot during takeoff and landing, is designed to take over this in-flight chore. Plotter and slide rule will still be at hand for preflight planning and map work; but after takeoff, ADVISOR proposes to retire the E-6B to standby status, where it should be in a jet age. ADVISOR will actually save the crew some time.

Convair's involvement in ADVISOR tests originally grew out of interest of flight test men, headed by Don Germeraad, chief test pilot, in a takeoff monitor—a device that would warn a pilot when his runway acceleration is less than it should be. Several designs have been suggested and tried out by various manufacturers. In discussions between Convair and Oster engineers, it was brought out that the potentialities exist for a much more sophisticated computer.

Consider what a takeoff monitor must do: First, it must absorb information about airplane gross weight and the runway—altitude, temperature, etc. Then, it must supply information about the airplane characteristics—relative effects of the variables on acceleration at takeoff thrust, and the airplane's standard runway requirements. The monitor mechanism, in other words, must be tailored to reflect the applicable graphs in the flight handbook. Finally, the mechanism must integrate takeoff and runway variables with the aircraft characteristics and make the results of this computation available to the crew, by indicator, warning horn, or some other such means.

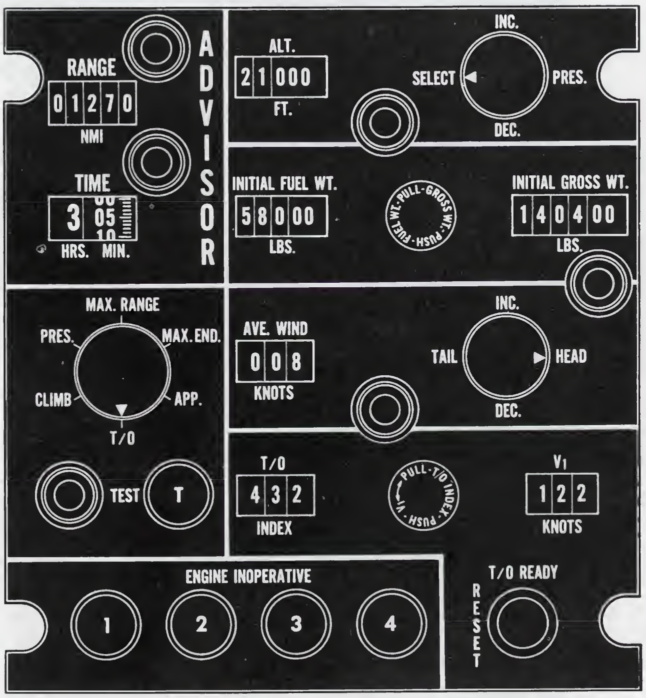
Such a takeoff monitor is possible, it is generally agreed. That being so, the reasoning was, why not go farther and build into the computer more of the airplane operating characteristics—mechanize more of the flight handbook? If the proper settings for flight characteristics at various speeds and altitudes are designed into the computer, all the data are at hand to solve standard cruise control problems. Parameters for fuel quantity, rate of fuel flow, outside air temperature, and airspeed are already available in instrument systems. As has been pointed out in recent Traveler articles on instrumentation, this information is available in the form of electrical signals, which can be fed into an electro-mechanical computer.

Outcome of consultations between Oster and Convair engineers was an arrangement whereby the Oster company, with long experience in manufacturing precision synchros and servo components, would make up the test units, and Convair in its flight test program would try them out. ADVISOR units were made up and installed in the first two "880" flight test aircraft. Each consists of a flight compartment control box and panel (pictured herein); a computer unit, acceleration switch, and altitude transducer (the only sensing unit in the ADVISOR system) in the electronics compartment; and a modification to the Kollsman indicated airspeed instrument to add a pair of triangular markers on the periphery of the dial.

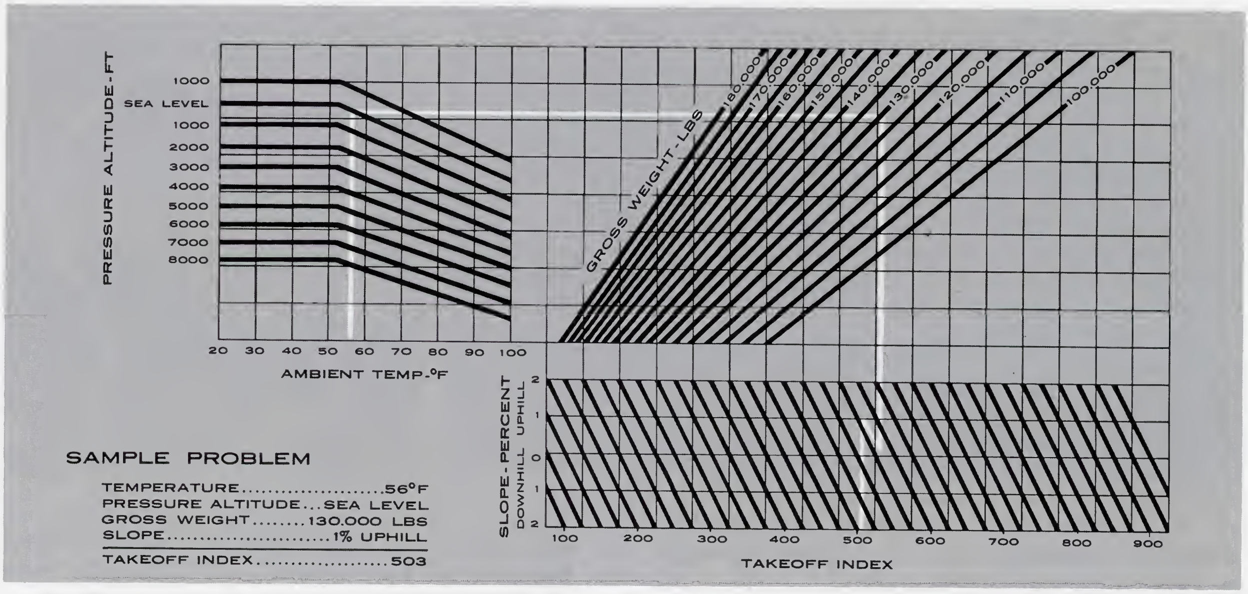
The indications are read on the IAS indicator and on a pair of digital counters at upper left on the ADVISOR panel. One of the markers on the IAS dial is for V_1 speed; the other, commonly termed the "bug," is an acceleration marker on takeoff, and a speed command marker in flight. Range and time remaining appear in the panel counters. A switch on the panel selects the mode in which the computer operates.

Following is the procedure for using ADVISOR in a typical flight, with a more detailed description of the indications given and the factors taken into account by the computer in each mode.

As part of preflight preparation, airplane gross weight and fuel weight are set into the control panel by use of a two-position knob (PUSH FUEL WT/PULL GROSS WT) on the panel. V_1 speed is determined from charts and set by the PULL position of another knob; also, the marker on the IAS indicator is manually moved to this V_1 speed, by rotating the dial cover glass.



"880" test ADVISOR panel is on copilot's RH console. Settings are typical for light-load takeoff. RANGE and TIME counters are normally masked during takeoff mode operation.

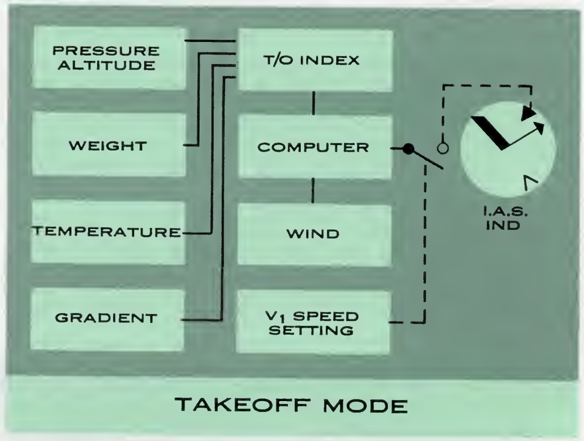


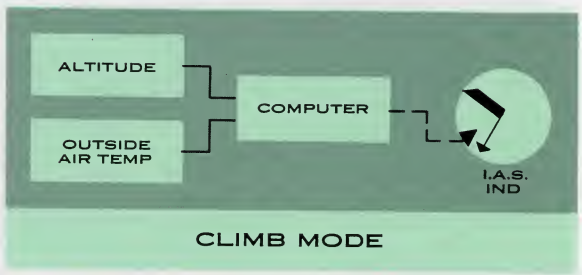
The PUSH position of the latter knob is labelled T/O INDEX, and a counter appears beside it. The takeoff index is an arbitrary figure. The pilot enters a chart with ambient temperature, pressure altitude, airplane gross weight, and runway gradient, and arrives at an index number representing a combined function for these variables. By means of the T/O INDEX knob, he sets this number on the adjacent counter.

Runway head or tail wind component is set into the average wind (AVE WIND) counter. The knob for this setting is turned left for tail wind, right for head wind. Finally, the mode selector is turned to T/O position, and a RESET button pushed. A green T/O READY light in the button illuminates if the system is armed.

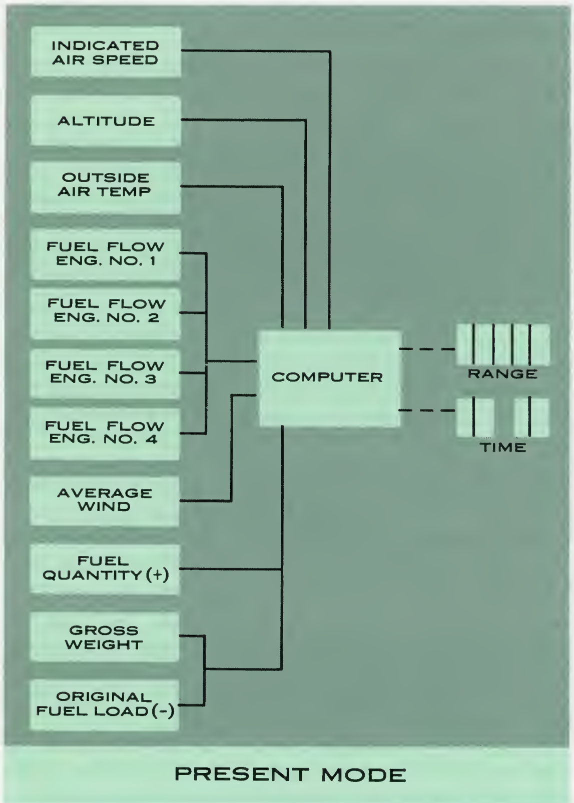
When brakes are released and the airplane begins its takeoff run, an acceleration switch closes, the green light extinguishes, and a timer begins feeding a signal into the computing mechanism. The timer signal represents a function of the acceleration at takeoff thrust necessary to meet the FAA-prescribed takeoff distance requirements; this signal is summed with the takeoff index and wind functions, to drive the bug on the IAS indicator.

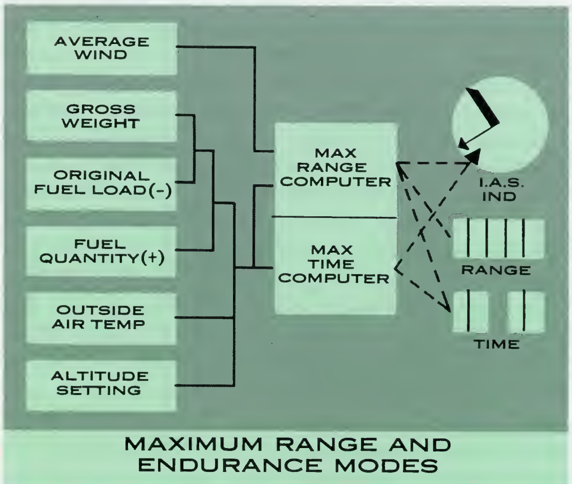
The bug moves around the airspeed dial at a steady rate, representing a safe minimum acceleration schedule, which will be somewhat less than normal takeoff acceleration. As airspeed builds up, the airspeed needle should quickly pass the bug and stay ahead of it up to V_1 speed. If the bug at any point in the run begins to creep up on the needle, acceleration is not normal. This may represent merely a puddle on the runway; however, it may mean reduced thrust, dragging brakes, or some other malfunction. In any case, if the bug overtakes the needle near V_1 speed, the takeoff should be aborted. At V_1 speed, since the airplane is committed, a switch cuts off the signal and the bug remains at V_1.

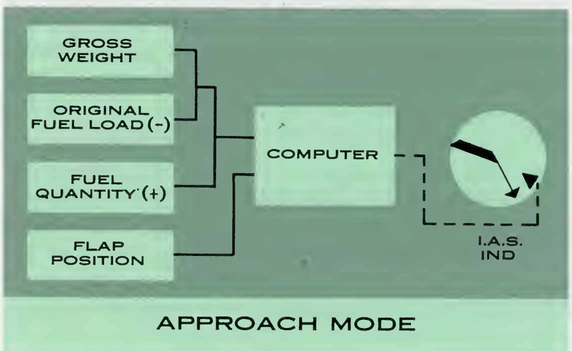




When the airplane is airborne, cleaned up, and throttled back to climb power setting, the mode selector switch is turned to CLIMB. Then the same bug moves around the IAS dial to mark the speed for optimum (maximum fuel economy) climb. The climb profile maintains a constant equivalent airspeed up to a certain true airspeed, and maintains the true airspeed for the rest of the climb. Optimum speed is computed from the altitude transducer and the outside air temperature signal supplied by the Kollsman Integrated Flight Instrument System (KIFIS).







For cruise control, there are three settings of the mode switch. To compute time and range remaining at present altitude and airspeed, average wind for the course is set into the AVE WIND counter, and the mode switch is turned to PRES. Range and time remaining appear on the ADVISOR panel digital counters.

This computation is perhaps the most complex of the various modes. Current fuel quantity is obtained from the Simmonds fuel gaging system; altitude from the altitude transducer; and outside air temperature and indicated airspeed from the KIFIS system. Gross weight setting on the panel counter is diminished by the amount of original fuel load, and present fuel load (from the fuel gaging signal) added back on, to yield a function for present weight. The fuel quantity signal is also fed directly to the computer. Rate of fuel consumption is obtained by summing the signals from the four General Electric engine fuel flow transducers. All these signals are combined with the built-in functions for aircraft performance, to drive the range and time counters.

When maximum range available at any specific altitude is required, the pilot uses the altitude selection knob, at the top of the panel shown. He sets in average wind as in PRES mode, and turns the mode switch to MAX RANGE. RANGE and TIME counters will turn to the proper figures, and the IAS bug will move to the required speed for obtaining maximum performance. If the airplane must climb to the selected altitude, the computer takes into account added fuel consumption during climb.

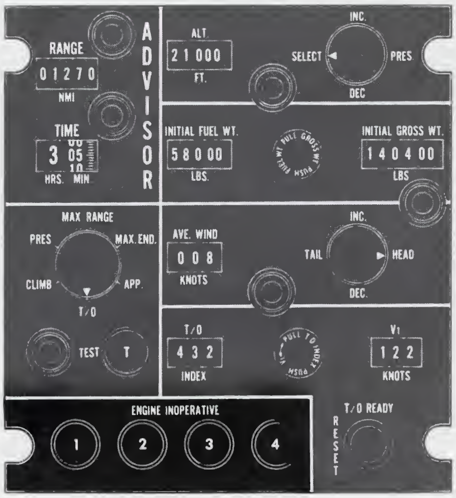
Finding the absolute maximum distance the airplane can fly entails finding the maximum of the maximum ranges at other altitudes. This can be quickly done by turning the ALT counter slowly up or down, until it is apparent that a peak reading has been reached on the RANGE counter. The ALT counter will then show optimum altitude for maximum range.

For maximum endurance at present altitude, or at any selected altitude, the same procedure is followed, with the mode switch at MAX END. The bug will show IAS for minimum fuel consumption, and maximum endurance time will appear on the TIME counter. Since range is usually not of primary importance in such a situation, the range counter will be masked off. Optimum altitude can be determined as in the range mode computation.

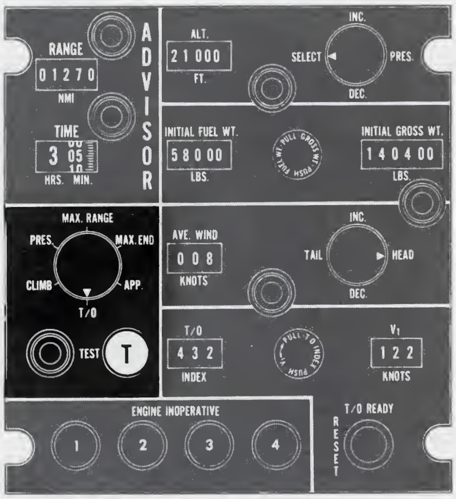
Computer inputs for maximum range and endurance modes are almost identical; the computer's parameters for performance are what change. Fuel aboard, and outside air temperature, are obtained from instrumentation. Gross weight is corrected by the fuel-aboard signal, and average wind is set in manually (for use in range computing only). In place of the signal for actual altitude, a signal representing the selected altitude is fed in via a potentiometer, controlled by the altitude selection mechanism.

Approach mode is one that interests some operators as much as takeoff mode. The mode switch is

turned to APP. The signal that drives the bug represents a margin over stall speed, which is a function of airplane maximum lift/drag ratio. Gross weight and flap setting are the variables. Flap setting is obtained from the flap position transmitter. The bug on the IAS will mark a minimum safe speed during approach, right on down to the over-the-fence phase of the landing.



Four buttons in the ENGINE INOPERATIVE section of the panel are for use in cruise computing modes. If No. 1 engine power is lost, or if the pilot merely considers shutting it down, pushing the No. 1 button will cause the computer to re-figure range and time, making allowance for loss of power and the aerodynamic effects of three-engine operation. The computer distinguishes between inboard and outboard engine-out drag and asymmetric trim. For two engines out, the signals are so summed as to provide proper readings for any combination of inboard and outboard engines, including two out on one side.



The TEST button beside the mode switch provides a means for a quick check of computer operation, either on the ground or in flight. Similar to the KIFIS test switch, it feeds in signals that represent certain settings of the range, time and wind counters and of the bug on the IAS dial.

Accuracy of ADVISOR was checked at better than 99% in the military bomber version. This does not mean, of course, that an airplane would run out of fuel on the exact mile that appears in the range counter; ADVISOR can be only as accurate as the information fed in, and neither fuel gaging systems nor performance charts are that precise. What the accuracy figure does mean is that a pilot has at his fingertips a mechanized handbook combined with calculator, which will give him, rapidly and automatically, an answer better than 99% of what he would get by the most meticulous calculation from his charts and instrument readings—and give him more answers in half a minute than he could work out in half an hour.

This immediate access to optimizing calculation is of primary importance in flying economy. In a survey of operations of one type of jet bomber over a year's time, it was found that fuel consumption degradation ran 5% to 8% from optimal; that is, the bombers used that much more fuel than they needed to, had the flights been planned with closer adherence to performance charts. With fuel loads at 50,000 to 100,000 pounds and more, percentages like that become important to commercial operators.

Other parameters — engine pressure ratio, total thrust, Mach number, or true airspeed, for example—can be used in such a computer, and other optima obtained. The ADVISOR configuration now being perfected in "880" test flights is adapted for the Convair jet airliners, to yield the information commercial operators need. It reflects the wide flying experience of Convair pilots in many types of aircraft. They turned thumbs down, for example, on a takeoff warning light or horn; during ground run, they had rather keep fire-alarm-size warnings for major emergencies. They did not care for an extra bank of engine thrust indicators, since pressure ratio and tailpipe temperature are fair measures of engine efficiency. They did request the takeoff warning on the IAS indicator, plainly visible to the pilot during the quick glance he can spare during takeoff roll.

As any electrical engineer well knows, it is always quite a way from an admittedly workable idea to reliable hardware. Since mid-1959, when the first ADVISOR began operating on "880" No. 1 test airplane, many components have been modified. "Shaped pots" have been reshaped, inputs have been juggled experimentally to yield varying types of readings. Flaws have been painstakingly weeded out and, so far as the "880" is concerned, finalized design is in sight.

When that time comes, John Oster Manufacturing Co. will have an ADVISOR ready for the production hardware stage; Convair will have made a necessary major contribution in a highly important field of development; and "880" and "990" operators will have available a device of great potential value with respect to flight safety and operating economy.

Sperry Instrument & Autopilot Systems

Convair 880 and 990

Three versions of Convair 880 and 990 aircraft are equipped with Sperry integrated flight and navigation instruments and the SP-30 autopilot. The behind-the-scenes components — radio receivers, compass and acceleration sensors, electronic modules, and servos — are for the most part identical or closely similar, although some systems have more elements than others.

In all versions, autopilot operation provides for 1) yaw damping and turn coordination, under either full manual or autopilot control; 2) for straight and level flight under gyroscopic attitude or barometric altitude control as desired; 3) for automatic interception and following of VOR radials or ILS localizers; and 4) for automatic glide path engagement.

The instruments provide airplane attitude and compass bearing, bearings to ADF and VOR stations, and deviation bars to show airplane position relative to radio beams and stations. There are available, however, a number of instrument and control panel configurations. Customer preferences have varied enough to result in some immediately apparent differences in the pilots' instruments and the autopilot control panels.

To prevent confusing the systems in these three versions of the Convair jet airliners, the typical navigation instruments and autopilot on some versions of the "880" will be described first. They are typical of the Sperry installations; the other two may then be compared with particular reference to their differences.

Integrated Instrument System

There are three basic instruments in the Sperry integrated flight instrument system: the C-6 Gyrosyn compass indicator, the HZ-4 attitude indicator, and the R-1 pictorial deviation indicator. A fourth indicator—the RMI, or Radio Magnetic Indicator (not a Sperry unit)—may be included among the navigation instruments.

The RMI need not be discussed in detail, since it is a standard instrument now familiar to most transport pilots. It has a rotating compass card governed by the compass system, and two pointers controlled by the two ADF low-frequency receivers. It will simultaneously give airplane heading and bearings of two selected low-frequency broadcast stations. The marker beacon light installation is also typical.

The RMI is mounted at the right-hand side of pilot's and copilot's instrument panels; marker beacon lights are just above it. The other three navigation instruments are at panel center, with the attitude indicator at the top, the compass below it, and the pictorial deviation indicator to the left of the compass.

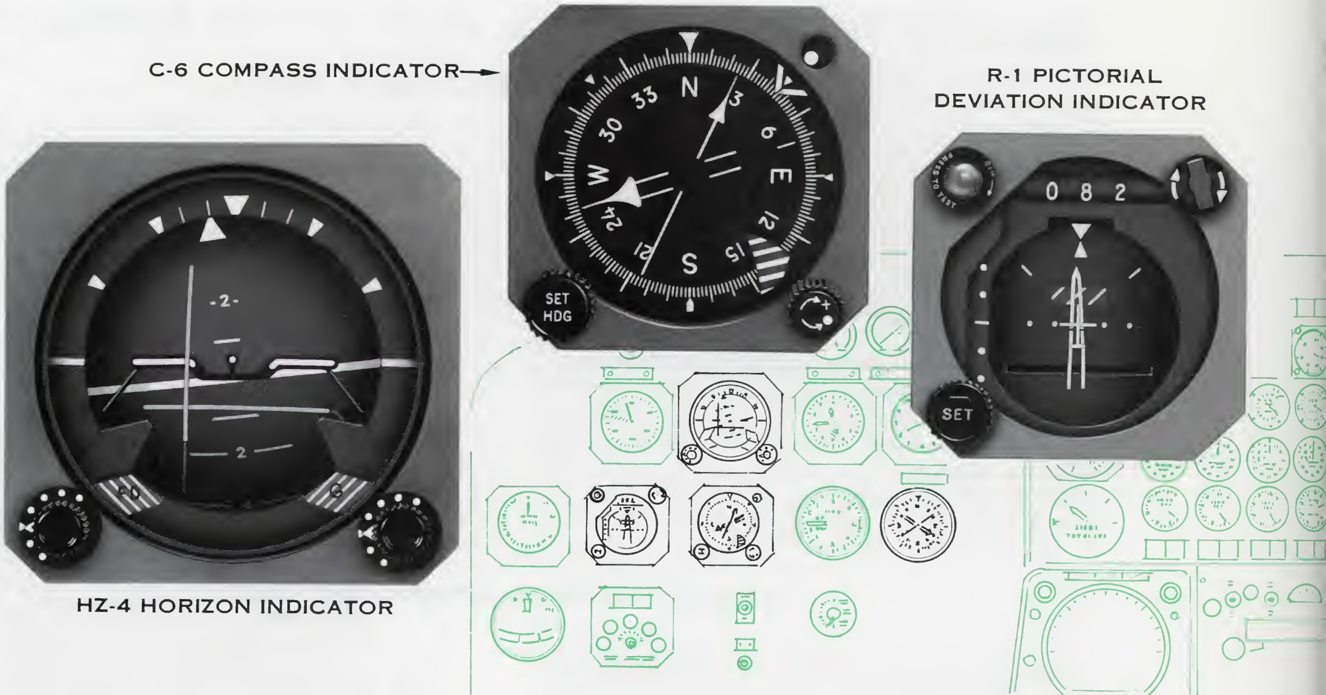
The C-6 compass indicator at first glance resembles the RMI, with two RMI pointers in addition to the azimuth card. These pointers, however, operate in conjunction with the VHF receivers and hence will give bearings of VOR stations tuned in. The instrument has command functions (preselect heading) in connection with the autopilot, which will be taken up later herein.

Compass and RMI azimuth cards are controlled by the C-10 compass systems. There are two complete systems and, as in most Convair aircraft, pilot and copilot panels have indicators for both systems. The pilot's compass indicator and copilot's RMI are controlled by one system, copilot's compass indicator and pilot's RMI by the other.

The compass has two modes, slaved magnetic and free gyro, selected by switches on the pilots' panels. In free gyro mode, the directional gyro maintains any heading, and the initial airplane heading is set manually on the dial by means of the synchronizing knob at the lower right-hand corner of the instrument. Gyro control provides a very accurate reference over short distances and may be used for grid navigation in polar regions. Random drift is held to a maximum of 3° per hour. Since this version of the "880" will be operating chiefly in lower latitudes, no latitude correction has been provided.

In slaved mode, the compass is still gyro stabilized. Actual gyro axis direction is of no importance; the magnetic heading and the gyro heading are synchronized either automatically or manually by rotating the indicator azimuth card. The magnetic sensor, a flux valve in the right wing tip, transmits its signal to a synchro in the instrument, rather than to the gyro unit. Any discrepancy between magnetic heading and that shown on the gyro-driven azimuth card will cause a small cross or dot to appear in an annunciator window in the upper right corner of the instrument. By turning the "sync" knob in the direction indicated by the annunciator, the card can be rapidly rotated until the window clears. Thereafter, any wandering of the gyro from magnetic heading will be corrected by slow slaving (1° to 2° per minute) of the gyro to the flux valve heading, via a signal from the instrument.

The horizon indicator, installed on some "880's," has no command functions, and the vertical and horizontal bars that are visible when power is off are biased out of sight after the vertical gyro erection is completed. The dial shows a black sphere with a white horizon line; the sphere rotates in both roll and pitch axes. Short horizontal lines above and below the horizon line can be read against a reference airplane, to indicate pitch angle; each line represents 10° nose-up or nose-down attitude. A roll index at the top is read against a pointer to show roll angle. Vertical gyro power failure will be indicated by a flag in the indicator.



The R-1 pictorial deviation indicator provides a representation of the airplane position with respect to a selected VOR radial or to an ILS localizer beam and glide slope. It includes course selection for the autopilot, mode indication, and warning flags.

When a VOR station is tuned in, the inbound bearing of the desired radial is selected by means of the SET knob; the bearing appears in a digital counter at the top of the instrument. A wedge pointer (V) appears on the dial, pointing along the radial toward the station, at an angle that represents the direction of the beam relative to the airplane heading. The "V" bar displacement from a fixed reference airplane symbol indicates the position of the airplane relative to the beam, and to the station.

As the airplane passes over the station and encounters the radio signal beyond the zone of confusion, a to-from sensor will rotate the "V" bar 180°. The pilot may prefer to set the outbound radial on the counter; if so, he may do so by using the reciprocal heading knob, on the upper right of the instrument. The digital counter will then indicate the outbound VOR radial bearing but the direction of the "V" bar will remain unchanged. The instrument will not give a false to-from reading in VOR operation; whatever course is selected, the "V" bar always points to the station.

In ILS operation, the course counter is set on the runway inbound bearing. The localizer is a single-direction signal and no to-from signal is available. Therefore the "V" will not invert even though the airplane passes over the localizer station. When a glide path signal is received, a glide slope bar appears and is deflected up or down from center to show the deviation of the airplane relative to the glide path.

Near the base of the "V" bar a window shows a flag with three positions, OFF, VOR, and LOC. The LOC flag is blue-yellow; the blue half will be on the right in normal approach. Should the airplane fly over and on past the runway, course setting should be left unchanged for go-around. The blue-yellow indication and "V" bar will remain as before. When the airplane makes the 180° turn, the "V" bar, being azimuth stabilized, will invert and be displaced toward the beam; the blue-yellow flag will swing around to the top of the dial, so that the blue indication will be on the left, emphasizing that the airplane is now on a reciprocal course. As the airplane turns again into the localizer beam, the "V" bar and blue-yellow flag will resume the normal approach pattern.

In event of compass malfunction, the R-1 can be used as a left-right deviation indicator by pulling out the SET knob and rotating the "V" bar until it points

A ELEVATOR SERVO
B RUDDER SERVO
C AILERON SERVO
D AFT PITCH ACCELEROMETER
E AFT YAW ACCELEROMETER
F LOWER ROLL ACCELEROMETER
G UPPER ROLL ACCELEROMETER
H STABILIZATION COMPUTER
J FWD PITCH ACCELEROMETER
K VERTICAL GYRO
L FLIGHT CONTROL COMPUTER
M FWD YAW ACCELEROMETER
N TRIM SERVO
P AUTOMATIC PILOT CONTROLLER
Q YAW DAMPER TESTER
R AUTOPILOT INDICATOR

vertically. This disengages the compass servo system and leaves the pointer in a vertical position, functioning as a simple right-left deviation bar.

Loss of radio signal will cause the VOR-LOC flag to indicate OFF. A glide slope warning flag marks loss of the glide slope signal.

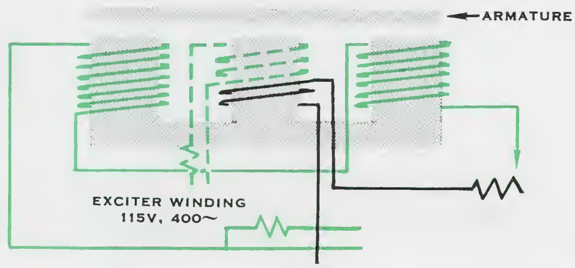
SP-30 Automatic Pilot

The SP-30 autopilot has four types of components (cockpit controls, electronics assemblies, servos, and sensors) arranged in the airframe as shown in the accompanying figure. In the flight compartment are the controller, indicator, and yaw damper tester. The controller, on the center pedestal, provides for autopilot engagement and mode switching. The indicator, on the instrument panel, contains autopilot trim meters and warning lights. The yaw damper tester, also on the instrument panel, provides a rapid preflight test of the airplane's yaw damper mode. The two electronic components — the flight control computer and stabilization computer — are located in the electronics compartment. There are three servos for the primary flight controls, plus a separate elevator trim servo.

The inertial sensors consist of the vertical gyro and six accelerometers. The vertical gyro is a conventional electrically-driven gyroscope that establishes roll and pitch displacement reference for both instrument system and autopilot.

The acceleration sensors are distinctive features of the SP-30 autopilot. There are six linear accelerometers, two for each airplane axis, taking the place of rate gyros. Each accelerometer is a simple and rugged transducer, weighing approximately 12 ounces. Essentially, it consists of an E-pickoff transformer and a leafspring-suspended armature, which acts as an inertial mass and also forms a path for magnetic flux. The E-shaped core of the transformer contains an excitation winding on the center leg and a signal-output

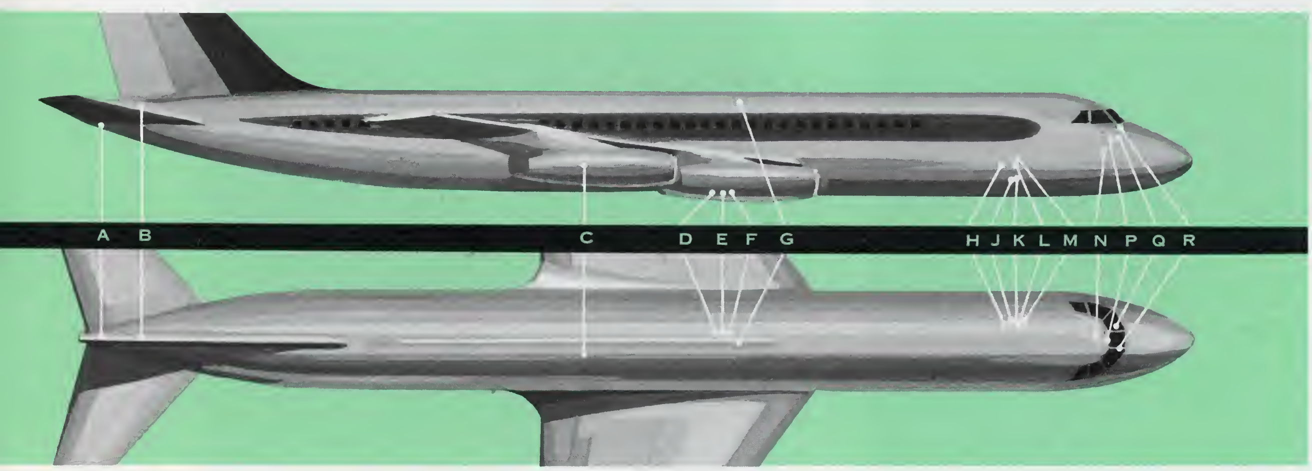
SCHEMATIC OF ACCELEROMETER



winding on each outer leg. Output windings are differentially connected to yield a null output under static conditions. Inertia of the suspended armature causes it to move under acceleration load, in the directions in which it is free to move. This varies the reluctance of the magnetic circuit, producing a signal in the output windings proportioned to acceleration rate.

For example, a vertically-oriented accelerometer near the airplane center of gravity yields a signal that is proportional to vertical acceleration of the airplane. When a second accelerometer is placed near the airplane nose and is oriented in the same direction, the electrical difference between the two signals is a measure of pitch angular acceleration. Yaw axis accelerometers are similarly located, but are oriented to measure lateral and yaw accelerations. Roll axis accelerometers, separated in a vertical plane, are both mounted near the CG at top and bottom of the fuselage.

Use of inertial stabilization, the Sperry Company maintains, provides quick response to gusts and tighter control of heading, attitude, and flight path. It makes possible a servo system with a high-torque gradient. The servo system employs both aircraft angular acceleration and servo tachometer data for feedback to close the servo loop. This permits the SP-30 to provide automatic gain adjustment of its control signals over the airplane's airspeed range, since variation in control surface effectiveness is compensated through the feedback from acceleration sensors.

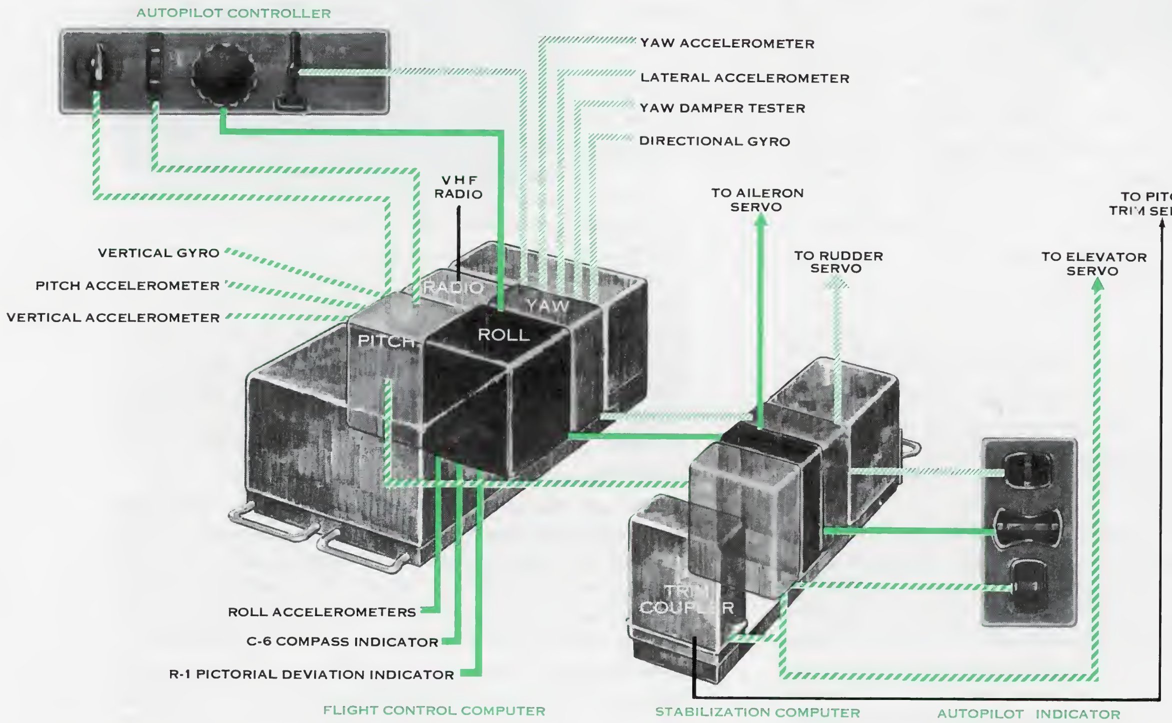


The "brain" of the SP-30 is the flight control computer, which collects data from the sensing and feedback elements and receives the command signals from the flight compartment and radio controls. It consists of a relay assembly, gain calibrator, and five plug-in modules.

Each axis — yaw, pitch, and roll — of the automatic pilot is provided with an individual plug-in command computer. These computers are composed of several "building-block" amplifier-shaping circuits and an electromechanical followup element. A fourth plug-in module is the pressure computer, to provide reference signals for constant altitude control. The altitude control unit is connected to pitot-static sources. A three-position pressure switch, sensitive to three ranges of pitot-static differential, controls autopilot parameters as a function of airspeed.

The fifth module is a radio coupler, to supply attitude-command signals to pitch and roll computers in accordance with radio beam data supplied by VOR and glide slope navigation receivers. The gain calibrator adapts the gains of the autopilot signals to the

AUTOMATIC PILOT SYSTEM




STABILIZER TRIM SERVO


SERVO DRIVE & BRACKET

AUTOPILOT CONTROL PANEL

specific requirements of the "880" and "990" aircraft, permitting interchangeability of other system components.

Signals from the flight control computer are amplified in a stabilization computer to drive the servos. The stabilization computer is also a plug-in modular unit, with three identical servo amplifiers, one for each axis, and an automatic cutoff.

The automatic cutoff continuously monitors SP-30 operation in roll and pitch axes by comparing signals from the accelerometers, vertical gyro, servo system input, and servo tachometers. It protects against unwarranted or excessive servo effect produced by failure in either of these axes. The yaw axis is not monitored during flight, but may be checked prior to flight by use of the yaw damper tester (optional equipment).

Two parts comprise the primary servo unit in each axis: a bracket, containing a cable drum and shaft; and a drive assembly consisting of a split-field dc series motor and tachometer assembly, a power gear train, and a clutch, splined to the servo bracket. The clutch is tooth type, being engaged by flexing rather than sliding action. The teeth are wide-angled, and the clutch is capable of being overridden by 150 to 200 percent of normal force applied on the control column. The horizontal stabilizer servo serves to relieve heavy trim loads in the elevator servo system.

The autopilot controller in the flight compartment is mounted on the pedestal between the pilots. The main servos-engage switch, to the right of panel center, has a visible detent at midpoint to engage the yaw damper, and is pushed on up to engage the autopilot.

Yaw damping supplements normal pilot control with automatic rudder action to damp out "Dutch roll" tendencies and provide coordination during turns. AUTOPILOT position of the switch engages rudder, elevator, and aileron servos to maintain three-axis control.

At left on the controller panel is the PITCH SELECTOR switch. PITCH KNOB position is essentially an "off" position for altitude hold, allowing pitch rate commands to be set in with the PITCH knob. When the pitch selector is at ALT, the pressure computer will hold the airplane at the altitude where the switch was engaged.

At the right of the panel is the TURN SELECTOR rotary switch for selection of four modes of operation. They are as follows:

1. TURN KNOB position is a mode that in other installations has been termed "manual" or "attitude hold." The autopilot will maintain the airplane in straight and level flight under command of the directional and vertical gyros. Coordinated turns can be made by use of the TURN knob at panel center, within a 35° bank angle limitation. Pitch maneuvers with the PITCH knob are limited to $\pm 15°$ pitch angle. Center position of the TURN knob has a detent, with a definite snap action as the knob is rotated from center. It is not self-centering, and must be returned to detent to bring the airplane back to wings-level. The PITCH knob is self-centering when released; it returns to neutral, and the airplane remains in the attitude existing upon release.

2. HDG-SEL mode is for following a compass heading preselected by means of the SET HDG knob on the C-6 compass indicator. The knob drives an index on the circumference of the compass card to the chosen heading and, on actuation of the autopilot mode switch, the autopilot will turn the airplane into the heading and maintain it there.

3. LOC-VOR mode is for interception and following of omnirange and ILS localizer radio beams. In VOR operation, the omniradial heading is set on the R-1 deviation indicator with the SET knob. The VHF navigation radio is tuned to the desired VOR or ILS frequency, and the beam approached at any angle under 90°. When the selector switch is turned to LOC-VOR, if the signal is above the minimum strength required for autopilot operation, the airplane will automatically approach the localizer beam or VOR radial and follow it. In ILS operation, the inbound heading may be set on the R-1 to monitor the approach pictorially; but, the autopilot is under direct radio control and will follow the localizer beam regardless of R-1 setting.

4. GLIDE PATH mode permits automatic approach to the glide path along the localizer beam, and automatic engagement and following of the glide path down as far as the pilot wishes to go under automatic control.

Two options are provided for manual disengagement of the autopilot. The servos-engage switch can be pulled back to YAW DAMPER, leaving yaw damping engaged, or to OFF, disengaging the yaw damper also. When this is done, an AUTOPILOT OFF warning light on the pilot's panel illuminates. Also, on each pilot's control wheel is an AUTOPILOT OFF release

YAW DAMPER TESTER

button, which returns the servos-engage switch to OFF without illuminating the warning light. If the engage switch is used to cut off the autopilot, the warning light can be extinguished by using the control wheel release button. The engage switch is a positive, "make-before-break" type which will always disengage the autopilot.

Electrical interlocks give command priority to the TURN and PITCH knobs on the autopilot controller. Altitude control and glide path modes are instantly canceled when the PITCH knob is displaced from center. Preselected heading control, localizer, or omnirange control modes are canceled when the TURN knob is moved from center detent.

The yaw damper tester is a built-in ground test circuit that transmits signals to the yaw damper system to simulate airplane yaw acceleration. A single push-button operates the assembly; a double light assembly indicates HOLD if the yaw damper system is malfunctioning, or READY if it is operating normally.

The autopilot indicator, on the center instrument panel, has three trim meters to give visual indications of rudder, aileron, and elevator servo trim conditions. At right of the trim indicators are the AUTOPILOT OFF warning red light, an amber GLIDE PATH ARMED light to show that the glide slope signal is being received, and an amber AUTO TRIM OFF light to indicate pitch trim malfunction. The glide path light extinguishes when the glide path is engaged.

AUTOPILOT INDICATOR

Flight Director & Autopilot

"990". MODEL 30-6

The principal difference between the Convair 990 Model 30-6 instrument system and that previously described is that this airplane has flight director components in the system.

The flight director gives the pilot a means of achieving increased accuracy in omnirange flying, approaches, and precise maintenance of heading and attitude. The system operates in conjunction with a flight director computer and the vertical and horizontal command bars in the HZ-4 horizon indicator.

Where standard deviation-bar indicators show relative displacement of the airplane from a projected flight path, the command bars, under computer control, show the proper action to be taken for flying a heading or course. Deviation bars would be centered when the airplane is on the desired flight path, regardless of its attitude; the HZ-4 command bars are centered when the airplane is in the proper attitude for flying to or maintaining a path.

A six-position selector switch determines the mode in which the system will operate. The switch positions are as follows:

SB — standby, in which the command bars are biased out of view, with the HZ-4 merely a horizon indicator.

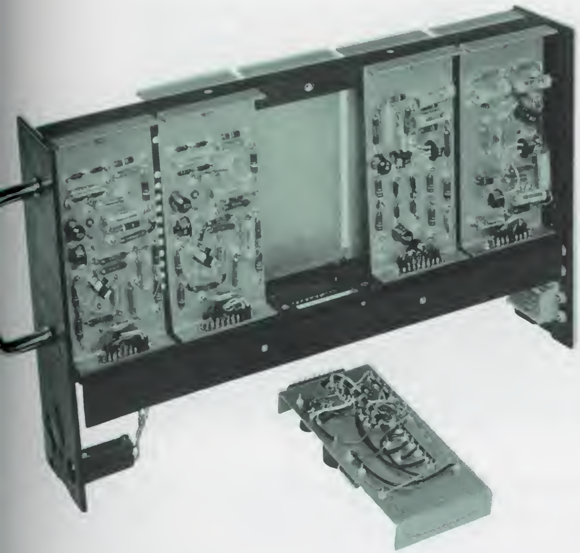
BL — blue left, for flying a back-beam approach to a localizer.

FI — flight instrument, in which the vertical command bar is referenced to the heading set on the C-6 compass by the SET HDG knob.

VOR-LOC — omnirange-localizer, for flying to and along a VOR radial or ILS localizer beam. The radial or ILS runway inbound bearing must be set on the R-1 pictorial deviation indicator by the SET knob and will show in the digital counter on the R-1.

APP — approach mode, in which computed glide slope information is displayed on the horizontal command bar.

HZ-4 HORIZON INDICATOR



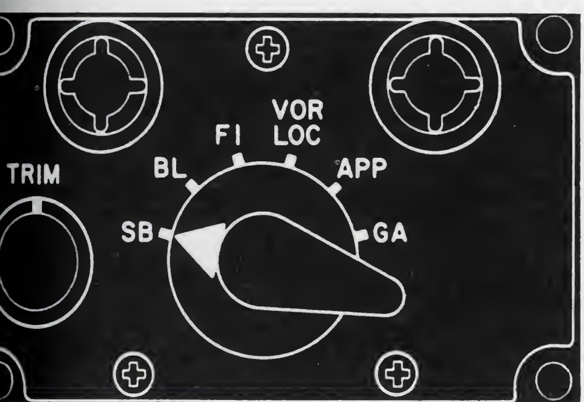
FLIGHT DIRECTOR COMPUTER

GA — go-around, in which the horizontal bar is biased upward to command a predetermined climb-out attitude and the aircraft heading at the time of switching becomes the vertical bar computed climb-out heading.

In BL, FI, and VOR-LOC modes, the horizontal bar displays computed signals to maintain the proper commands for level flight. There is no flight director mode for altitude hold in this installation.

In all modes, "flying to the needle" so as to keep the command bars centered will cause the airplane to turn toward the selected heading or course, approach it asymptotically, and fly along it. In flying radio beams, as with autopilot operation, wind correction will be automatic.

The Model 30-6 autopilot differs from that already described in two particulars: this airplane does not have the yaw damper tester; and the elevator trim mechanism is hydraulic rather than electric, so that autopilot trim operates by solenoid valves rather than by a servo motor.



MODE SELECTOR FLIGHT DIRECTOR SYSTEM

Flight Director & Autopilot

"990" MODEL 30-5

The Convair 990 Model 30-5 differs markedly from the two versions previously described in instrument configuration.

The changes have the effect of making the indicators, autopilot control panel, and some operational characteristics somewhat resemble the Bendix Series 200 flight director and PB-20 autopilot systems. However, since the components are Sperry, the instrumentation is not identical with the Bendix flight director indication.

Each pilot's instrument panel display has a horizon director indicator at the center top position; a course deviation indicator under it; and a radio magnetic direction indicator to the right of the course deviation indicator. In the lower right-hand corner of the pilot's panel are switches for flight director mode selection and for compass systems.

The compass systems are the Sperry C-10, already described herein. Compass indications appear on both the radio magnetic direction indicator (RMDI) and the course deviation indicator (CDI), on rotating compass cards with lubber lines at the top.

The RMDI is the primary compass indicator; the CDI azimuth card is slaved to it. An annunciator for aligning the gyro and flux valves appears in the upper left corner of the RMDI; the synchronizing knob is in the upper right corner. The slaving mechanism is similar to that previously described. The "sync" knob may be pulled out to allow free gyro control of the compass cards.

The RMDI has two conventional radio directional needles, showing bearings of two selected ADF stations, two VOR stations, or one of each. Switches at the lower corners of the instrument are used to control selection between ADF and VOR receivers.

The CDI has, inside the azimuth card, a radio-beam directional and deviation bar, showing lateral and angular displacement of the airplane from the localizer beam center or from the VOR radial selected. A to-

C-6E COMPASS INDICATOR

from arrowhead shows relative position of VOR stations.

A knob at lower left sets a course for flight director system or autopilot use, by positioning an inverted T cursor on the azimuth card, and simultaneously shows the bearing in a digital counter at upper left on the instrument face. Preselect heading, for flight director or autopilot, is set by the knob at lower right, which positions a heading cursor on the azimuth card. The CDI has a horizontal glide slope deviation bar, which is always biased out of view in this installation. In emergency loss of compass signal, pulling the course knob out allows the azimuth card to be rotated until the deviation bar is vertical; it then may be followed as if it were a simple left-right deviation bar, so that the airplane can be flown to a radio beam without reference to compass heading.

HZ-5 HORIZON INDICATOR

The horizon director indicator (HDI) shows a disk, of which the upper half is blue and the lower half black, to indicate roll attitude. Since it is a disk and not a sphere, it does not show pitch angle; this is shown by a "servoed" miniature aircraft which moves up and down within a plus or minus 34° pitch attitude range. The miniature aircraft may be trimmed by the knob at lower left.

To the left of the horizon disk is a glide slope display consisting of a vertical row of dots and a short horizontal glide slope bar.

A deviation-command steering needle. pivoted at the bottom of the dial, is displaced from vertical, left or right, in response either to signals from the VHF radio receivers, or to computer signals combining roll, heading, and radio information. At the lower right is a DEV-STEER knob having two positions, 180° apart. When the DEV lettering is uppermost, the needle shows relative distance and the general left-right direction of VOR/ILS beams.

When the knob is rotated to STEER position, the steering needle is under control of the flight computer.

R-4B COURSE DEVIATION INDICATOR

If computer input is from the compass system, the steering needle deflection will be a command to turn toward the heading set on the CDI by the heading select knob. As the pilot enters into a turn toward the needle, it will center; by keeping it centered, the pilot will level out on the heading chosen.

If computer input is from the VHF radio, the needle deflection will command a turn toward the VOR radial or localizer beam center, on a course set on the CDI by the course select knob. By flying to the needle, the pilot will approach the beam asymptotically.

Summarizing: (1) Compass heading appears on the RMDI and CDI. (2) Radio course deviation appears on the CDI, and on the HDI when the knob is in DEV position. Glide slope deviation appears on the HDI. (3) Preselect heading and course are set into the CDI. (4) When the HDI knob is in STEER position, directional commands from the computer govern the steering needle, to aid in approaching and maintaining magnetic or VOR/ILS courses. (5) The command system does not function in connection with pitch attitude, either for glide slope or for altitude hold.

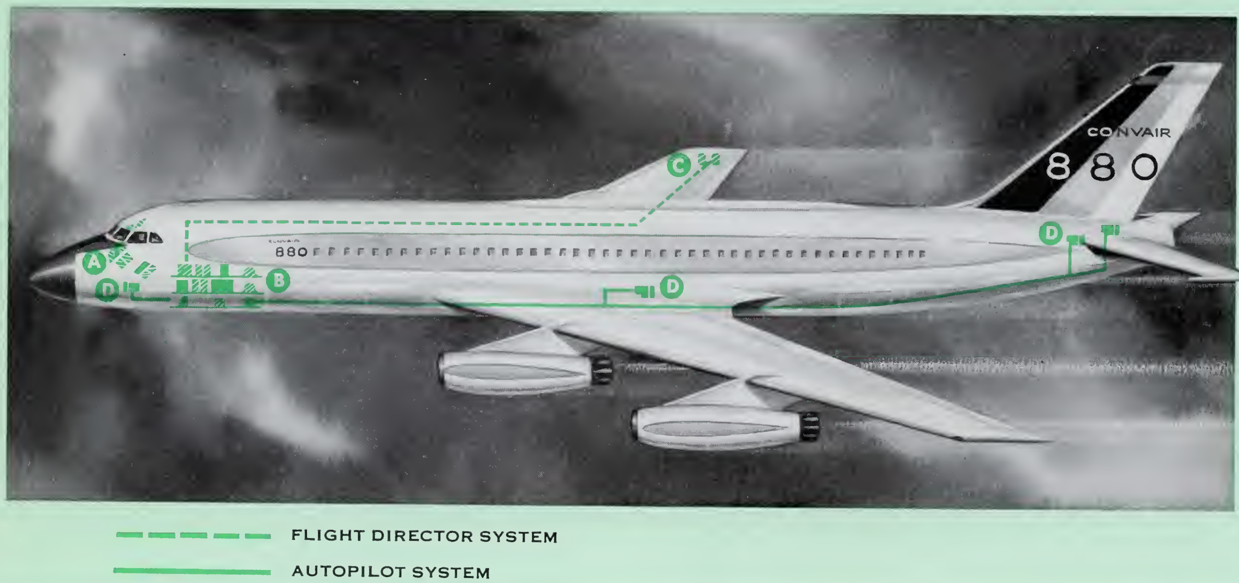
The autopilot controller panel differs from the standard Sperry installation. The altitude hold control is a toggle switch rather than a knob. One reset button has been added for the AUTOPILOT OFF warning light. On the mode selector switch, the terms HDG SEL and TURN KNOB have been replaced by HDG and MAN respectively, but the functions of the autopilot in these positions are unchanged.

Heading and course for HDG and VOR-LOC modes are set on the CDI. The trim indicator, at upper right on the instrument panel, is similar to that previously described. There is no yaw damper tester in this installation, and elevator trim is hydraulic, as in the Model 30-6 installation.

One difference in the autopilot-off warning system may be noted: When the autopilot is turned off by any means — automatically, by the engage lever, or by the release buttons on the control column — the AUTOPILOT OFF light on the panel will illuminate, as will a light in the reset button on the autopilot controller panel. Pressing the reset button will then extinguish both lights.

BENDIX Flight Director & Autopilot Systems

Series 300 Flight Director, and PB-20 Autopilot



Flight Director and Autopilot Systems comprise (A) instruments and controls, (B) electronic compartment components, (C) compass flux gate sensors, and (D) control surface servo motors.

It is not yet quite practical to build an airplane in which the pilot can dial "Chicago" on his control panel and then sit by while the airplane takes off and proceeds to destination. Still, the designers have come a long way towards this end, and they are obviously going farther. When a pilot first steps into the cockpit of his brand new jet airliner, he may find provisions on his panels for equipment to be installed when facilities are ready, or even for devices still being developed.

At the other extreme, the tried-and-true cannot be dispensed with. Though he may never use it, the pilot will find on his 1960-model instrument panel the oldest of navigational aids, a plain magnetic compass; and another instrument as basic to flight as a binnacle to a ship at sea, the ball turn-and-bank indicator.

Between the old and the not-yet-perfected is the equipment with which the pilot will do most of his flying. In the Convair 880 and 990 jet transports, he will have the best available.

The pilot will be able to set up instructions on his panels for his airplane to fly at a certain altitude in a certain direction, and then sit back and watch it fly the exact heading for hours, if he so desires. He can couple his autopilot to an omnirange radial beam and let it find the radial; work out the wind correction; and follow the beam to and over the station, and on away from it until an instrument flag warns him that the beam has faded out.

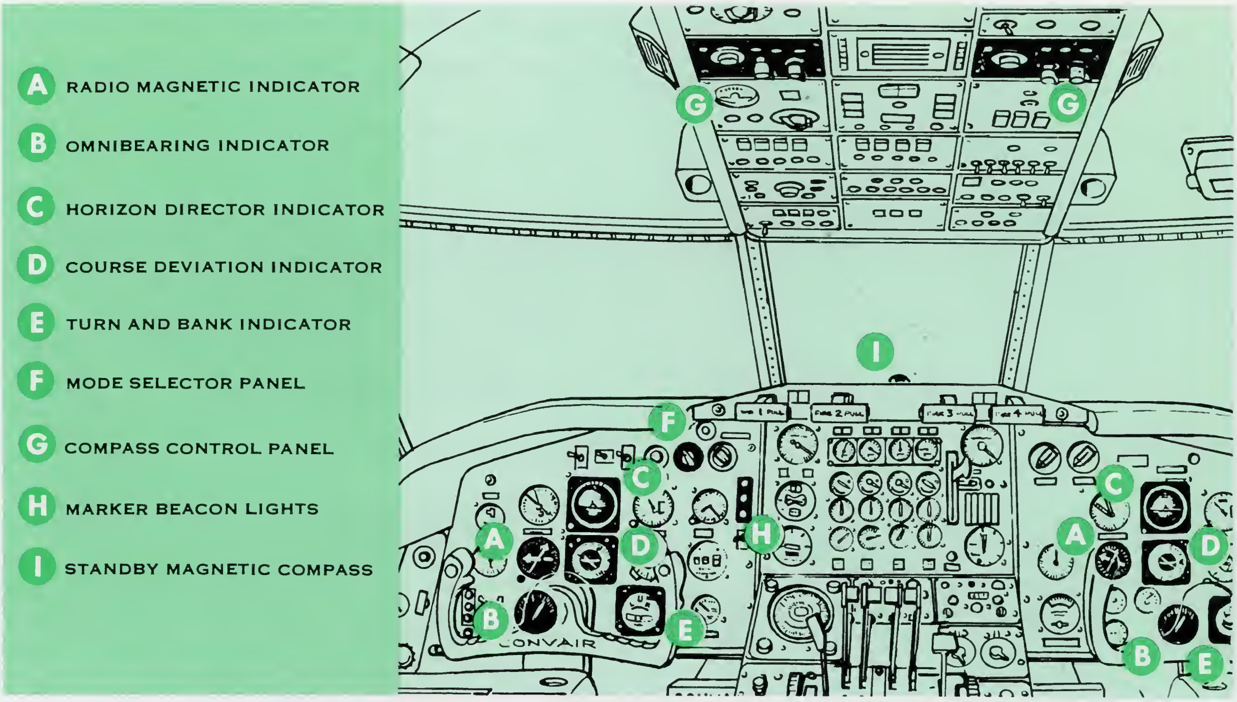
Landing, he can tune his radio to an ILS station and sit by while the airplane finds the center of the beam and glide path, and follows the path down to a few feet from the runway.

Instruments give him a continuous report on his bearings, relative to compass and/or the radio beams in which he is interested. They give him the flight attitude of his airplane and, in some installations, specific instructions on how to fly or intercept a desired course, detailed to the point of telling him at what angle he should be banking.

Much of this instrumentation and automation represents recent development in equipment, generally familiar to most pilots today. Radio direction-finding, for example, dates from the 1920's, and the two-needle radio magnetic indicator is now standard equipment. Automatic pitch and yaw control was developed to a high degree of effectiveness during World War II. Some automatic pilots in recent years have provided straight and level flight, turn coordination, altitude control, and glide path lock-on.

What is new in today's jet airliners is, first, the concentration of navigational information in instrument display; second, the refinement in precision of control; and, third, the extent of automation possible.

Either of two flight director and autopilot systems are installed on "880" and "990" aircraft: the Bendix Polar Path compass system, instrumentation, and PB-20G autopilot in some Convair 880's, and the



Pilots' flight director instruments and control panels.

Sperry Gyrosyn compass, instrumentation, and SP-30 autopilot in other "880's" and in the "990."

The two systems provide approximately the same instrument information and autopilot operation, but there are differences in operational details and instrument displays. Because most readers will be interested in one or the other system, the Traveler will take them up separately. This issue is concerned primarily with the Bendix (Eclipse-Pioneer) instruments and autopilot. The Sperry systems will be discussed in a future issue.

Flight Director System

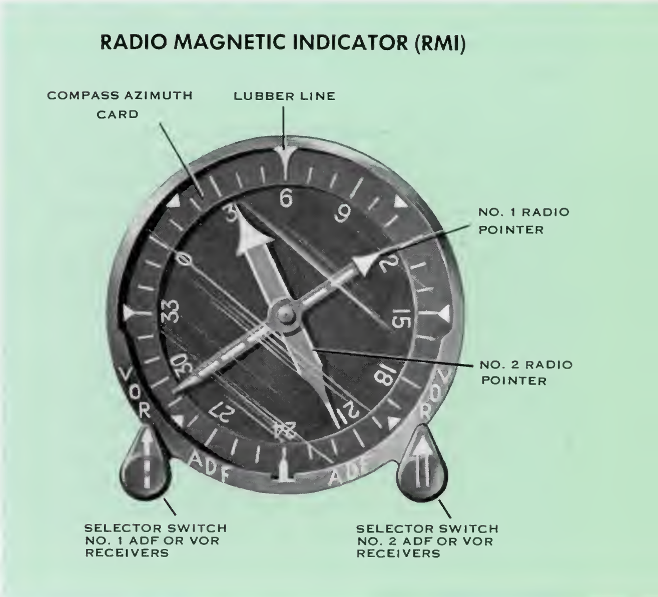
Compass, radio, and airplane attitude information is provided for both navigation instruments and autopilot. Since part of autopilot control is provided via the instruments, it may be well to examine them first.

Familiar instruments on the Convair 880 pilot's and copilot's panels will include the turn-and-bank indicator, omni-bearing indicator (OBI), radio magnetic indicator (RMI), and marker beacon indicator lights. The turn-and-bank is lower right on each pilot's panel; the OBI, showing bearing of the VOR station tuned in, is lower left. Marker beacon lights are upper right. A single standby magnetic compass is mounted above the center panel.

The RMI is similar to that in the Convair-Liners, with some capabilities added. The RMI now operates with either standard broadcast or VHF radio signals. The two needles can respond to the two ADF receivers, to the two VHF navigation receivers, or to one of each. The compass card is part of the compass system.

In the center of the panel are the two principal flight director instruments. The upper is the horizon director indicator; the lower is the course deviation indicator.

The horizon director has command functions, governed by a flight selector mode switch located above and to the right of the dial. When the flight



steering computer is not in use — mode selector switch in OFF position — the indicator serves as a conventional vertical-gyro-controlled artificial horizon. It shows an attitude sphere, the upper half light blue and the lower half black, with an airplane reference line at dial center. A pitch trim knob in the lower left corner trims the sphere within a range of 11° up to 6° down, to establish a nose-up or nose-down flight attitude if desired. At the top of the sphere is a pointer that moves against reference markings on the indicator face to indicate roll angle. Markings are at 10°, 20°, 30°, and 45°.

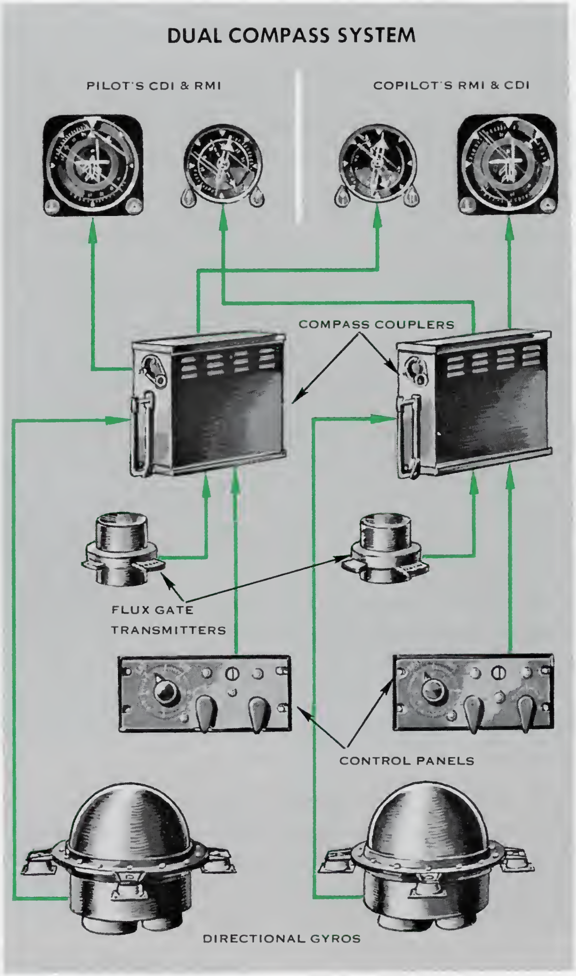
The course deviation indicator (CDI) combines in one instrument compass heading, omni-bearing selection, localizer or VOR beam indication, VOR to-from indication, glide slope indication, and radio warning and compass power failure flags. It also provides course and heading settings for manual or autopilot operation.

This is quite a bit of information and function for one four-inch-square instrument. The CDI, however, bears enough resemblance to other flight instruments in current use that pilots have less difficulty than the layman might suppose, once they have familiarized themselves with the dial patterns.

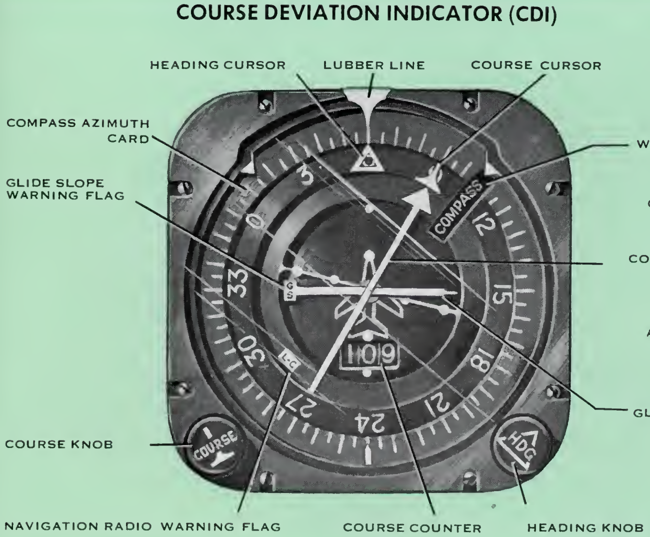
In essence, the CDI face shows airplane compass heading and position relative to selected VOR or ILS beams. These indications are independent of the flight steering computer and of the autopilot. The compass information and its sources may be examined first, and then the indications in VOR and ILS navigation.

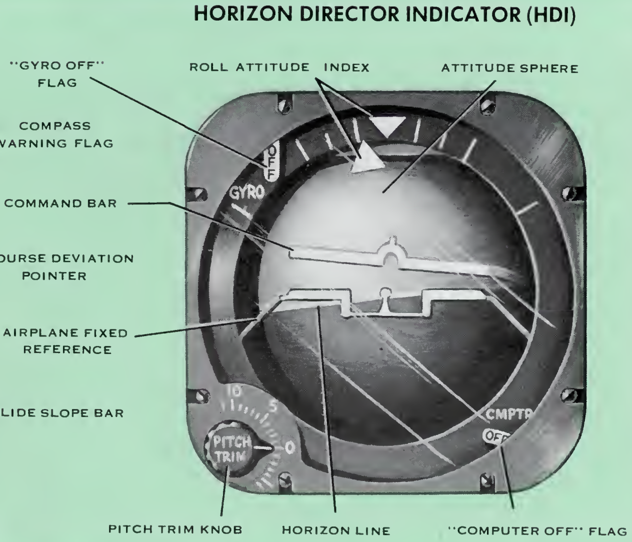
POLAR PATH COMPASS SYSTEM

The compass heading is the primary frame of reference. The CDI azimuth card, on the outer rim of the dial, is a replica of that on the RMI, controlled



Each of the two complete compass systems govern indications on pilot's and copilot's instruments.





by the same compass systems. Airplane heading is under the lubber line at the top.

The Bendix Polar Path compass system is the remote-magnetic gyro-controlled type. Where magnetic readings are stable, at middle and lower latitudes, the gyro can be slaved to the earth's magnetic field. This is sensed by a flux gate transmitter in the right wing tip. A special knob setting allows rapid slaving of the compass card to the flux gate transmission.

Over long distances, the slaved mode is usually more reliable. Directional gyro control, under gyroscopic direction only, is very accurate for short-term reference, and is essential for flight at high latitudes where magnetic indications are unreliable. Since gyro drift caused by rotation of the earth is greatest near the poles, a special device has been added to compensate for the apparent drift. This is set by a latitude correction dial on the compass control panel (overhead). Random drift, caused by friction and other such inescapable factors, is held to a maximum of 1 1/2° in 30 minutes.

The resolving unit for signals from the flux gate compass and directional gyro is the compass coupler. Its output goes to the RMI, CDI, and to the autopilot.

There are two complete compass systems — two flux gates, two gyros, two couplers and control panels. Output of one is to the pilot's CDI, output of the other to the copilot's. The RMI's are criss-crossed, so to speak; the pilot's compass system operates the copilot's RMI and vice versa, so that each has on his panel indications from both systems and, hence, will quickly notice any discrepancy caused by compass system malfunction.

COURSE DEVIATION INDICATOR & HORIZON INDICATOR

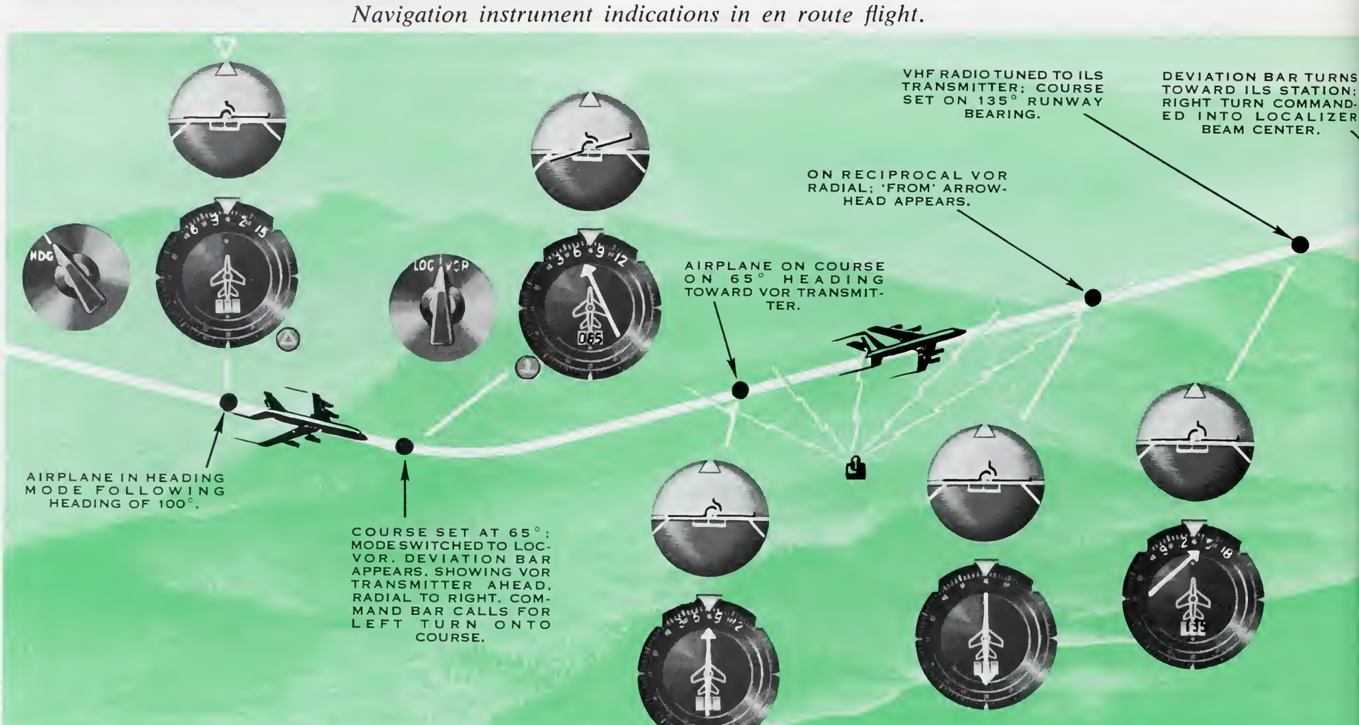
Inside the CDI azimuth card is the radio beam information. To follow a VOR radial, the pilot — or copilot — tunes in his VHF radio to the selected station and sets into his CDI the radial he wishes to follow. This he does by turning the COURSE knob on the lower left corner of the instrument. The knob positions an inverted T on the azimuth card, and also turns a counter in the lower half of the dial. At a 30° selected course, for example, the T will be at the figure 30; the counter will show 030; and the lubber line at the top will show actual heading of the airplane.

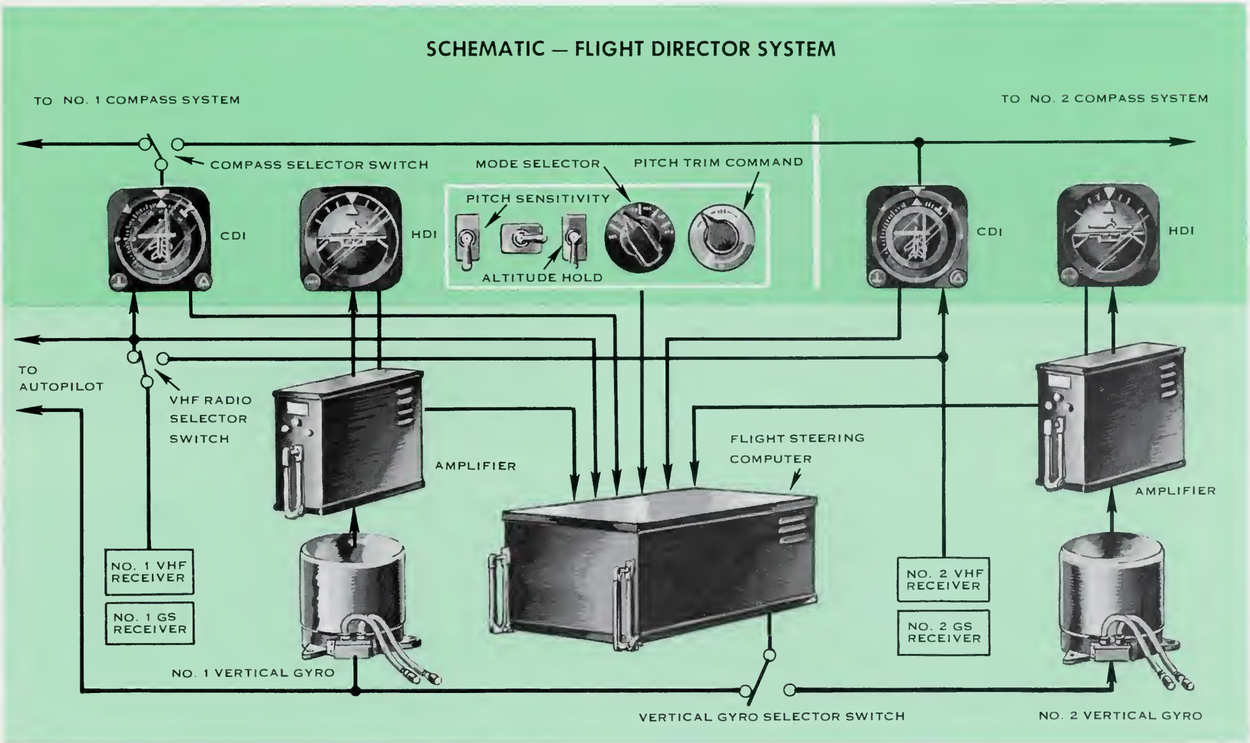
Simultaneously, a deviation bar appears inside the azimuth ring, representing the VOR beam selected. It points along the beam — that is, it shows the beam direction relative to the airplane heading; and it is displaced laterally to show location of the beam relative to airplane location. In the center of the dial is outlined a small airplane symbol for reference. If the radial is ahead to the left of the airplane, crossing the airplane's projected path at 40° angle, for example, the bar will be at 40° from vertical, above and to the left of the symbol.

When the VOR station is ahead of the airplane, a triangle appears just inside the inverted T cursor; if the VOR station has been passed, the triangle appears opposite, at 180° from the T.

In ILS operation, the pilot or copilot tunes in the station and sets the localizer inbound runway bearing

Navigation instrument indications in en route flight.

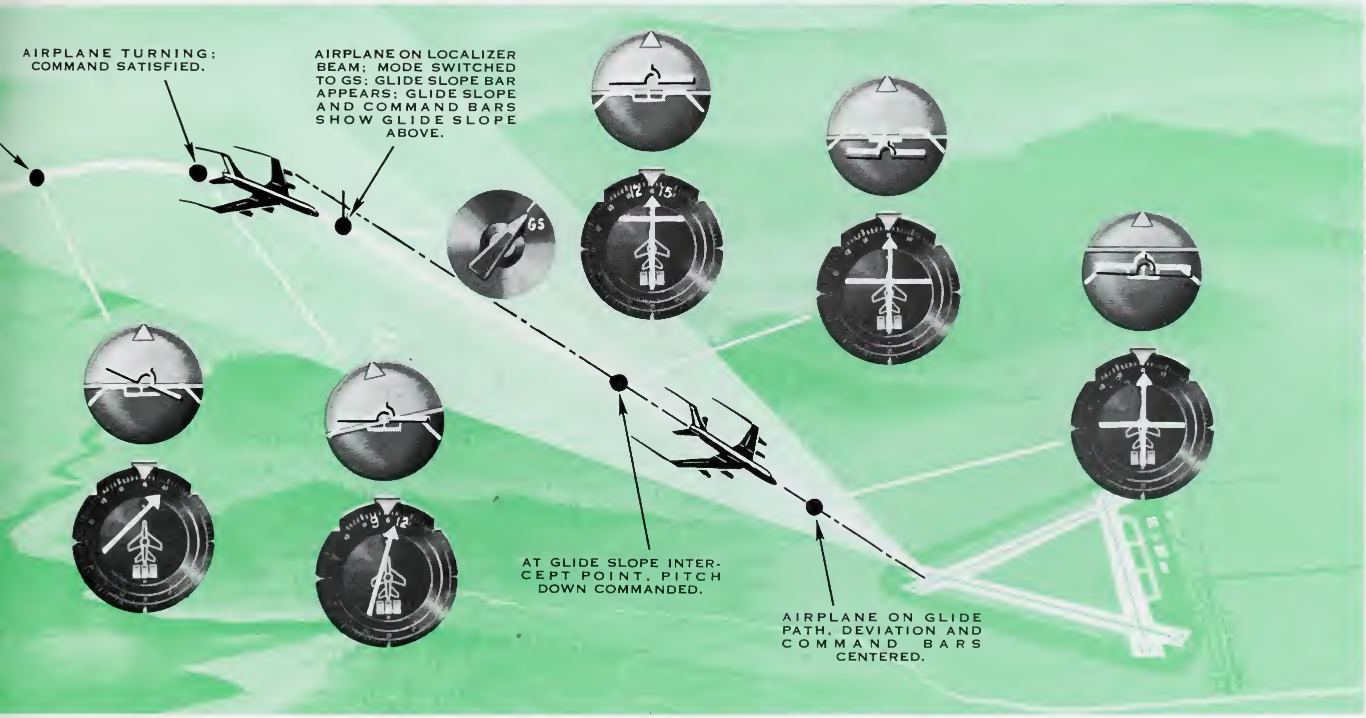




into the CDI by the COURSE knob. As with VOR, the deviation bar appears to show the localizer beam direction and location with respect to the airplane. The to-from triangles do not show in connection with a localizer beam.

When an ILS localizer is tuned in, the glide slope receiver is automatically tuned to proper frequency. The glide slope signal adds a second bar on the CDI, a horizontal line, displaced up or down from center to show relative location of the glide slope.

Navigation instrument indications during ILS approach.



FLIGHT DIRECTOR

It may be seen that the CDI, while not a command instrument, can be used to fly a radio beam, by a "follow the needle" technique. The flight director system provides a much more sensitive method of following either a compass course or a radio beam, by adding a command bar, governed by the flight steering computer, to the Horizon Director Indicator.

The mode selector switch beside the horizon indicator has three modes on its dial: heading, localizer-VOR, and glide slope. A fourth mode, altitude hold, is controlled by a separate switch. The pilot may fly these indications in full manual control — by control column and rudder pedals — or by manual manipulation of the autopilot pitch and turn knobs. (Autopilot operation in equivalent modes is explained later herein.)

1. In HDG mode, the pilot, by turning the HDG knob on the lower right-hand corner, sets into the CDI the heading he wishes to follow. The selection is shown on the azimuth scale card by an arrowhead, which turns with the card. The command bar will then indicate what bank angle is required to turn immediately into the selected compass heading. The pilot follows the bar — if the bar slants down to the right, he turns right. By keeping the command bar aligned with the artificial horizon, he will turn and straighten out at the desired heading. If the airplane wanders, the command bar will indicate the corrective action.

2. In VOR-LOC mode, when the pilot sets the selected course into the CDI, the horizon indicator bar will direct a turn bank toward the selected VOR radial, or toward the center of the localizer beam, and will give him continuous instructions on flying to and along the beam. The computer will automatically develop the required wind correction angle.

3. In GS mode, the glide slope receiver will add its signal, and the command bar will show nose-up, nose-down and/or bank angle required to capture and hold to the glide path.

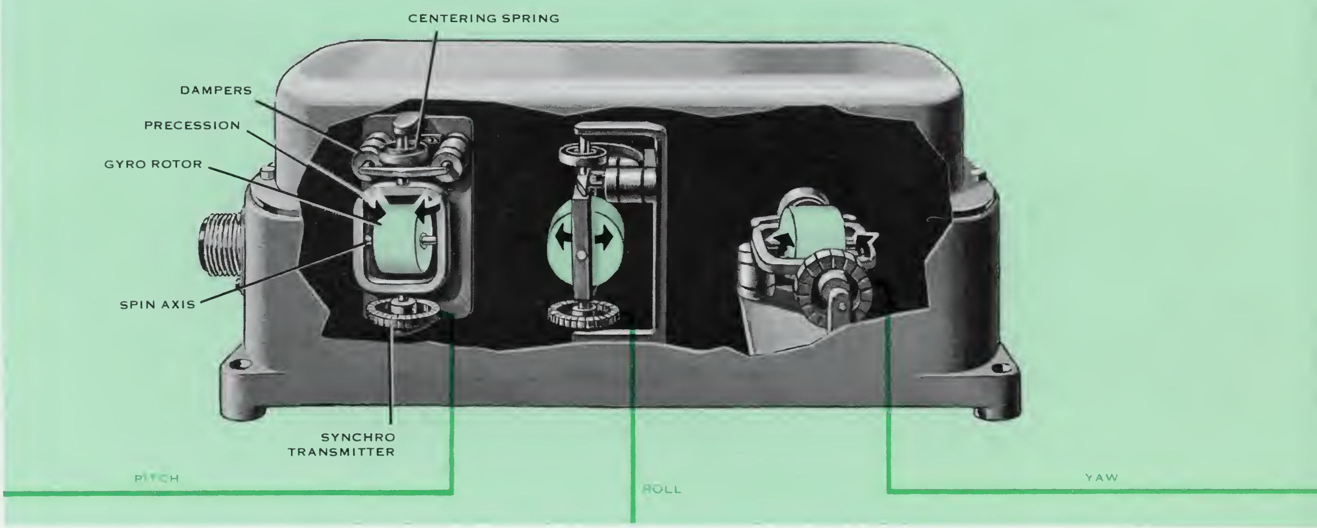
4. Altitude hold mode is engaged by a separate switch on the pilot's instrument panel. With the switch at ON, the horizon command bar is controlled in pitch as a function of altitude. Flying so as to keep the command bar at vertical center will hold the airplane at the altitude at the time of switch engagement.

Extra sensitivity has been added to the "880" horizon director command bar. High and low sensitivity selection can be made by a two-position switch on the pilot's instrument panel.

As has been noted, the horizon indicator reverts to a conventional gyro horizon when the mode selector switch is at OFF. Should the pilot's vertical gyro system malfunction, he can switch to the copilot's system gyro for primary attitude function. The pilot may also, if necessary, select the copilot's compass system for his CDI by means of a transfer switch on his instrument panel. He may switch his CDI to signals from the copilot's VHF or glide slope receivers; however, in such a case, both course settings must be identical.

An emergency operation by radio reference alone is provided in the CDI. The course knob can be pulled out to disengage the compass dial servo, and the whole rotating display can be rotated by the knob until the course deviation bar is perpendicular. This bar will remain under radio control and will indicate the relative displacement of the airplane from the VOR radial or localizer beam center. Under these conditions a red flag will emerge in the lower left corner of the CDI.

SCHEMATIC — AUTOPILOT THREE-AXIS RATE SENSORS



Bendix PB-20 Autopilot

The autopilot is a high-gain, transistorized system. Its basic signals are received (1) from the magnetic, gyroscopic, and radio sources that operate the flight director instruments; (2) from gyroscopic rate sensors in the three axes of the airplane; and (3) from instructions set into the pilot's CDI.

In brief summary of the gyroscopic controls, it may be noted that the vertical and directional gyros, already mentioned in connection with flight instruments, are displacement type; the electrical signal picked off is proportional to amount of gyro displacement, or precession, and hence to amount of change in airplane attitude. The autopilot sensors are rate gyros; by confining gyro precession to a small range and spring-loading the mounting of the gimbals, the electrical signal picked off is made proportional to rate of airplane attitude change rather than to amount of change. Rate sensors have been found essential for automatic control of high-speed aircraft; control response is quicker and is proportioned to deflecting forces.

The autopilot control panel is mounted on the pedestal between the pilots, accessible to both. At the right on the panel is a switch with three positions, OFF, AUTOPILOT, and DAMPER.

The DAMPER position engages only the yaw damper, which operates in connection with the rudder. Since human reaction time is too slow for consistently stable directional control at high speeds, yaw dampers are currently used in jet aircraft almost all the time after takeoff until landing.

With the switch in AUTOPILOT position, yaw damping is always engaged. There are five autopilot modes available, selected by the multiposition switch at the left end of the panel. A separate altitude hold switch is at the right end of the panel. With the switch in ALT position, in all modes except when locked on glide slope, the airplane will hold level flight at the altitude at which the switch was actuated.

AUTOPILOT MODES

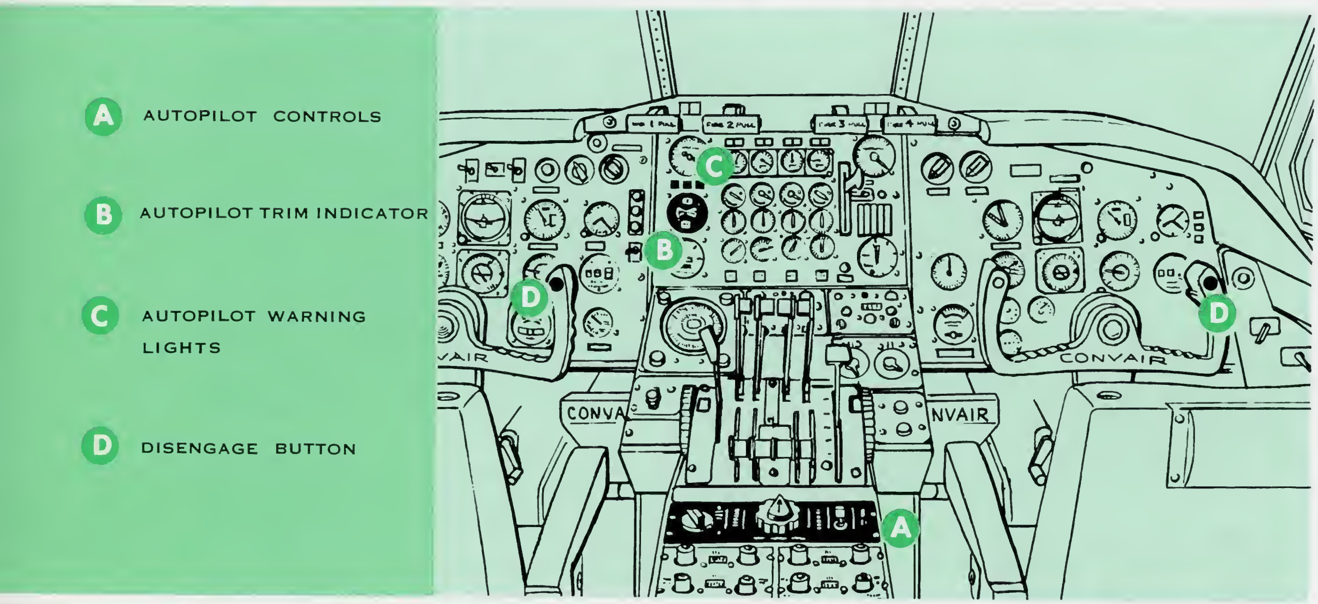
The operation of the autopilot in the five modes is as follows:

1. With the switch at MAN, the airplane holds automatically whatever heading it has at the time of engagement. The autopilot is under control of the compass system, either gyro or magnetic, as determined by the compass control setting.

Changes in heading, however, can be made by the TURN knob in the center of the panel. When the knob is rotated, signals are fed to the aileron control channels and the airplane enters into a smooth turn; it continues to turn until the knob is returned to the center detent. The compass system then resumes control, and the airplane will continue on the new heading.

Pitch angle can be controlled by the pitch wheels, located on each side of the TURN knob. They rotate together to operate the elevator servo, and also the trim servo that moves the horizontal stabilizer. The airplane will nose up or down, and will then maintain whatever pitch angle it holds at the time the wheels are stopped.

The pitch wheel is disconnected by a magnetic clutch when the altitude hold switch is on, or when



Autopilot instruments, warning lights, and controls.

glide slope is engaged. In all modes, the stabilizer will be trimmed constantly, to relieve aerodynamic load on the elevator and to unload the elevator servo. When the mode is changed from altitude hold or glide slope to manual, a friction device and holding coil maintain the trim already set into the controller, so that transition to manual control will be smooth.

2. In HDG mode, the pilot sets the heading he wishes into the course deviation indicator by means of the heading knob. Then, when the autopilot mode switch is turned on HDG, the existing compass heading signal is replaced by the preset heading signal, and the airplane will execute a coordinated turn into the heading. If the pilot wishes to change course, he need only turn the HDG knob to the new setting, and the airplane will follow as he turns the knob.

3. In LOC-VOR operation, the pilot, by turning the COURSE knob, presets in the CDI the bearing of either the VOR radial he wants to follow or of the localizer beam of an ILS station. He tunes in the station and then switches to LOC-VOR mode. The autopilot will then make the proper turns to approach the beam asymptotically and will follow the beam, automatically developing the proper wind correction angle.

4. In GS AUTO (glide slope automatic) position of the mode switch, the autopilot will continue to hold the center of the localizer beam until the glide slope is intercepted. In this mode, interception must be from below. At interception, altitude hold will be automatically disengaged, and the airplane will nose down and follow the glide path.

5. GS MAN (glide slope manual) permits capture of the glide slope under manual control. Whereas automatic glide slope engagement is a recent development, GS MAN provides the pilot essentially the same method of capturing the glide path that he had in most transports of the Convair-Liner generation. He can approach the glide path in LOC-VOR autopilot mode from either below or above, and then switch to GS MAN for lock-on. From this point on, autopilot operation is identical with that in GS AUTO mode.

Autopilot trim indicator shows servo trim load. Warning lights are AUTOPILOT OFF, PITCH TRIM OFF, or GLIDE SLOPE ARMED (for automatic intercept).

INTERLOCK & WARNING SYSTEMS

The autopilot mode selector switch is springloaded to MAN position, and is held in other positions by energized solenoids. The TURN knob has a priority in all autopilot modes. When it is rotated more than 5° left or right, microswitches cut off all compass or radio directional signals and deenergize the holding solenoid, so that the switch returns to MAN. Unless the TURN knob is in the center detent, the mode selector switch will not stay in any position but MAN, and the autopilot cannot be turned on.

Similarly, the AUTOPILOT-DAMPER and altitude control switches are springloaded to OFF and held in other positions by solenoids. On each pilot control wheel is an autopilot disengage button; when it is depressed, the holding solenoids are deenergized, and autopilot, altitude hold, and yaw damping are all disengaged. The airplane is instantly under full manual control. The yaw damper may be re-engaged after a manual takeover.

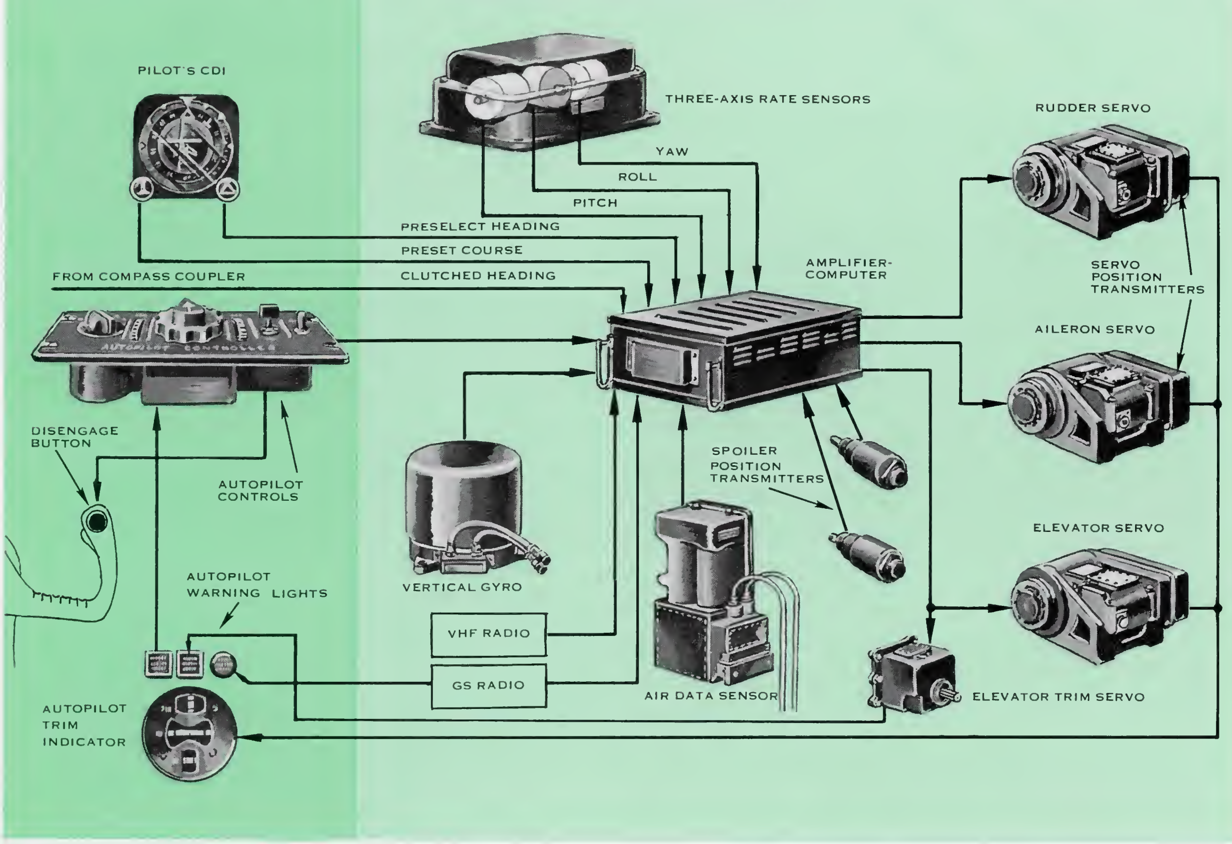
Interlock relays in the autopilot system monitor the 115/200-volt electrical supply, and disengage the autopilot by deenergizing the switch solenoids in the event of power failure. A number of other conditions that would prevent satisfactory yaw damping or autopilot operation will cause the interlock circuitry to prevent autopilot engagement.

Near the pilot's side of the center instrument panel is a row of three warning lights. The left one shows flashing red if the autopilot is disengaged by the interlock circuitry, indicating malfunction, or if the autopilot is turned off by means of the panel switch. Pressing the control wheel disengage buttons will turn the light off.

Illumination of the red center light indicates that pitch is out of trim. This light operates only in approach configuration — specifically, when the flaps are down. The right-hand GS ARMED blue light comes on when GS AUTO is selected, to indicate that the glide slope has not yet been intercepted; it extinguishes when the glide slope signal takes control of the autopilot.

The autopilot system provides for automatic pitch trim, but not for rudder or aileron trim. During auto-

SCHEMATIC — AUTOPILOT SYSTEM



pilot operation, an out-of-trim condition will not be apparent in airplane attitude, since the autopilot servos will hold against the unbalanced pressures; some warning is therefore needed to show when control surfaces need trimming, so that sustained loading can be removed from the servos. Warning is provided by a three-axis trim indicator on the left side of the center panel. Out-of-trim is indicated by the movement of white bars in small windows in the instrument face; a sustained deflection of the vertical rudder bar to the right, for example, means that the rudder should be trimmed to turn the airplane right.

AUTOPILOT COMPONENTS

The basic sensors that govern autopilot operation have been mentioned. In brief summary, the components of the system are as follows:

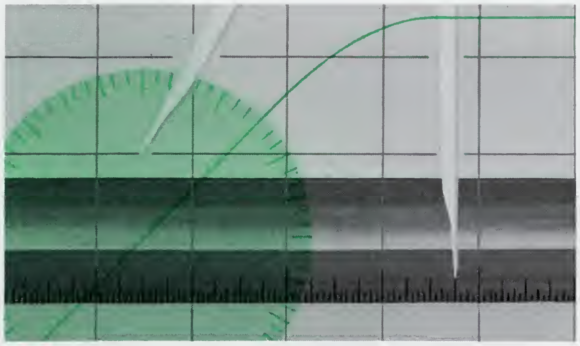
The three gyro-actuated rate signal transmitters are mounted on a common base. The gimbal axes are oriented to each airplane axis; the rate signals are transmitted to an amplifier-computer unit by Autosyn synchros.

Static and dynamic air pressures are important factors in automatic flight control. Pitot and static pressures are conducted to the air data sensor, a high-precision instrument that supplies a signal proportioned to indicated airspeed, and another proportional to altitude, to modify autopilot loop gains.

Rate gyro, compass, vertical gyro, radio, and surface follow-up signals are fed into the amplifier-computer; its output is to the servo motors that position the control surfaces. The computer unit is located in the electronics compartment and contains the electro-mechanical computers, limiters, relays, and transformers for autopilot control. The components are miniaturized plug-in card assemblies which can be quickly interchanged. Transistors, diodes, and magnetic amplifiers are used for amplification and phase discrimination.

Power is supplied through a power junction box. An adapter unit in the electronic rack contains potentiometer adjustments for adapting the autopilot to the particular flight characteristics of the airplane.

The servos that move the control surfaces are two-phase induction motors, operating the control cables through gear trains and magnetic clutches. Autosyn synchros on the output shafts transmit signals for follow-up; spoiler position is monitored by a special position transmitter. Rudder, elevator, and aileron servo motors have electrical resistance torque limiters, and a slip-clutch and torque limit disconnect. The elevator trim servo that operates the stabilizer has a slip-clutch and is electrically torque-limited to ensure safe operation.



CONVAIR 990

Dimensions, Stations and Station Geometry, Access Doors and Service Panels

For the convenience of those who plan to service, maintain, and provide terminal facilities for the Convair 990 jet airliner, the pages following present dimensional data and airplane access information in a form available for quick reference.

Basic stations are given for wing bulkheads (pages 244, 245), empennage ribs (246, 247), fuselage belt-frames (pages 248, 249), and engine pods (pages 252, 253). Numbering of bulkheads, ribs, and access doors is according to systems used in Convair drawing references. Since wing and empennage have multiple station patterns, some of the geometry is given for orientation and for possible cross-reference use.

Overall dimensions of the "990" are on pages 248, 249. On pages 250, 251 are locations and actual heights from ground of the principal airplane service points, empty and fully-loaded conditions.

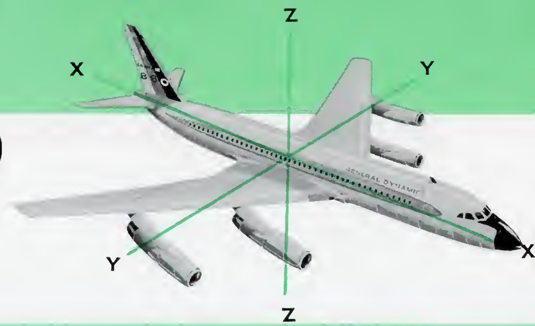
CONVAIR 990
DRAWING NUMBERING SYSTEM

30-X X XXX

- Specific drawing number
- Area
- Group function
- Model

30-0	GENERAL (proposals, specifications, general airplane)
30-1	WING AND EMPENNAGE
-11	Horizontal stabilizer
-12	Elevator
-13	Leading edges
-14	Vertical stabilizer & dorsal
-15	Rudder
-16	Wing
-17	Wing & trailing edge
-18	Aileron, tabs & flaps
-19	Wing tip and spoilers
30-2	POWER PLANT & AIR CONDITIONING
-21	Wing (power plant)
-22	Engine assembly
-23	Engine inst and removal
-24	Pylon
-25	Pod
-26	Fan duct
-27	Bleed air and ducting
-28	Low pressure ducting
-29	Major air cond components
30-3	ELECTRONICS
-31	Electronics compt — fwd
-33	Electronics compt — aft
-34	Wing and nacelles
-35	Vertical stabilizer
30-4	CONTROLS
-41	Fuselage — nose
-42	Fuselage — intermediate
-43	Fuselage — aft
-44	Wing
-45	Nacelles
-46	Vertical stabilizer and rudder
-47	Horizontal stabilizer and rudder
-48	Nose gear
-49	Main gear
30-5	ALIGHTING GEAR
-51	Main gear
-52	Nose gear
-55	Doors and mechanisms — gear
-57	Doors and mechanisms — fuselage
30-6	ELECTRICAL
-61	Fuselage — nose
-62	Fuselage — under cabin floor
-63	Fuselage — cabin
-64	Wing and pylon
-65	Engine pod
-66	Empennage and aft fuselage
30-7	FUSELAGE
-71	Nose section
-72	Fwd constant section
-73	Overwing section
-74	Aft constant section
-75	Tail section
30-8	HYDRAULICS, H-P PNEUMATICS
-81	Fuselage — nose
-82	Fuselage — intermediate
-83	Fuselage — aft
-84	Wing
-85	Nacelles
-86	Vertical stabilizer & rudder
-87	Horizontal stabilizer
-88	Nose gear
-89	Main gear
30-9	FURNISHINGS & GROUND SUPPORT
-91	Flight compartment
-92	Fwd cabin
-93	Passenger cabin
-94	Aft cabin
-95	Under-floor area
-99	Ground support equipment

Convair 880



DIMENSIONS

STATIONS AND STATION GEOMETRY

ACCESS DOORS AND SERVICE POINTS

On pages 232 through 243 following are a number of dimensioned drawings of the Convair 880 jet airliner. Three kinds of information are presented:

1. Some basic orientation geometry, for general reference and for making clear the station nomenclature used in locating airplane positions in the "880." For example, there are six kinds of stations called out in wing drawings; on page 232 will be found basic reference and cross-reference points, with sufficient angular data for trigonometric use if desired. A center spar station at the spar centerline, for example, can be converted to fuselage buttock line by the formula

$$(\text{C S Sta})\ (\cos 7^\circ)\ (\cos 34^\circ\, 8'\, 12'')$$

and to fuselage station by

$$818.128 + (\text{C S Sta} - 271.540)\ (\sin 34^\circ\, 8'\, 12'')\ (\cos 2^\circ).$$

2. Structural and access door data. On page 233 will be found major wing bulkhead stations, with bulkheads numbered as they are on Convair drawings. Principal structure and mechanism access panels and doors are shown also numbered according to the Convair drawing system. These numbers differ from those later stenciled on wing and empennage panels.

3. Exterior dimensions. On pages 238 and 239, the conventional three-view drawings give data that establish terminal or hangar space requirements for an "880." On pages 242 and 243, service point locations are given with reference to airplane centerline, together with their approximate heights above ground.

Much of this data has been requested by operators planning servicing and terminal facilities for the "880." It is believed that as "880" aircraft go into service, these illustrations will provide a handy guide for quick reference.

CONVAIR 880 DRAWING NUMBERING SYSTEM

22-X X XXX
- Specific drawing number
- Area
- Group function
- Model

22-0 GENERAL (proposals, specifications, general airplane)

22-1 WING AND EMPENNAGE
-11 Horizontal stabilizer
-12 Elevator
-13 Dorsal
-14 Vertical stabilizer
-15 Rudder
-16 Wing
-17 Aileron
-18 Flaps
-19 Wing tip and spoilers

22-2 POWER PLANT & AIR CONDITIONING
-21 Wing (power plant)
-22 Engine assembly
-23 Engine inst and removal
-24 Pylon
-25 Pod
-26 Fuselage (power plant)
-27 Bleed air and ducting
-28 Low pressure ducting
-29 Major air cond components

22-3 ELECTRONICS
-31 Electronics compt — fwd
-33 Electronics compt — aft
-34 Wing and nacelles
-35 Vertical stabilizer

22-4 CONTROLS
-41 Fuselage — nose
-42 Fuselage — intermediate
-43 Fuselage — aft
-44 Wing
-45 Nacelles
-46 Vertical stabilizer and rudder
-47 Horizontal stabilizer and rudder
-48 Nose gear
-49 Main gear

22-5 ALIGHTING GEAR
-51 Main gear
-52 Nose gear
-55 Doors and mechanisms — gear
-57 Doors and mechanisms — fuselage

22-6 ELECTRICAL
-61 Fuselage — nose
-62 Fuselage — under cabin floor
-63 Fuselage — cabin
-64 Wing and pylon
-65 Engine pod
-66 Empennage and aft fuselage

22-7 FUSELAGE
-71 Nose section
-72 Fwd constant section
-73 Overwing section
-74 Aft constant section
-75 Tail section

22-8 HYDRAULICS, H-P PNEUMATICS
-81 Fuselage — nose
-82 Fuselage — intermediate
-83 Fuselage — aft
-84 Wing
-85 Nacelles
-86 Vertical stabilizer & rudder
-87 Horizontal stabilizer
-88 Nose gear
-89 Main gear

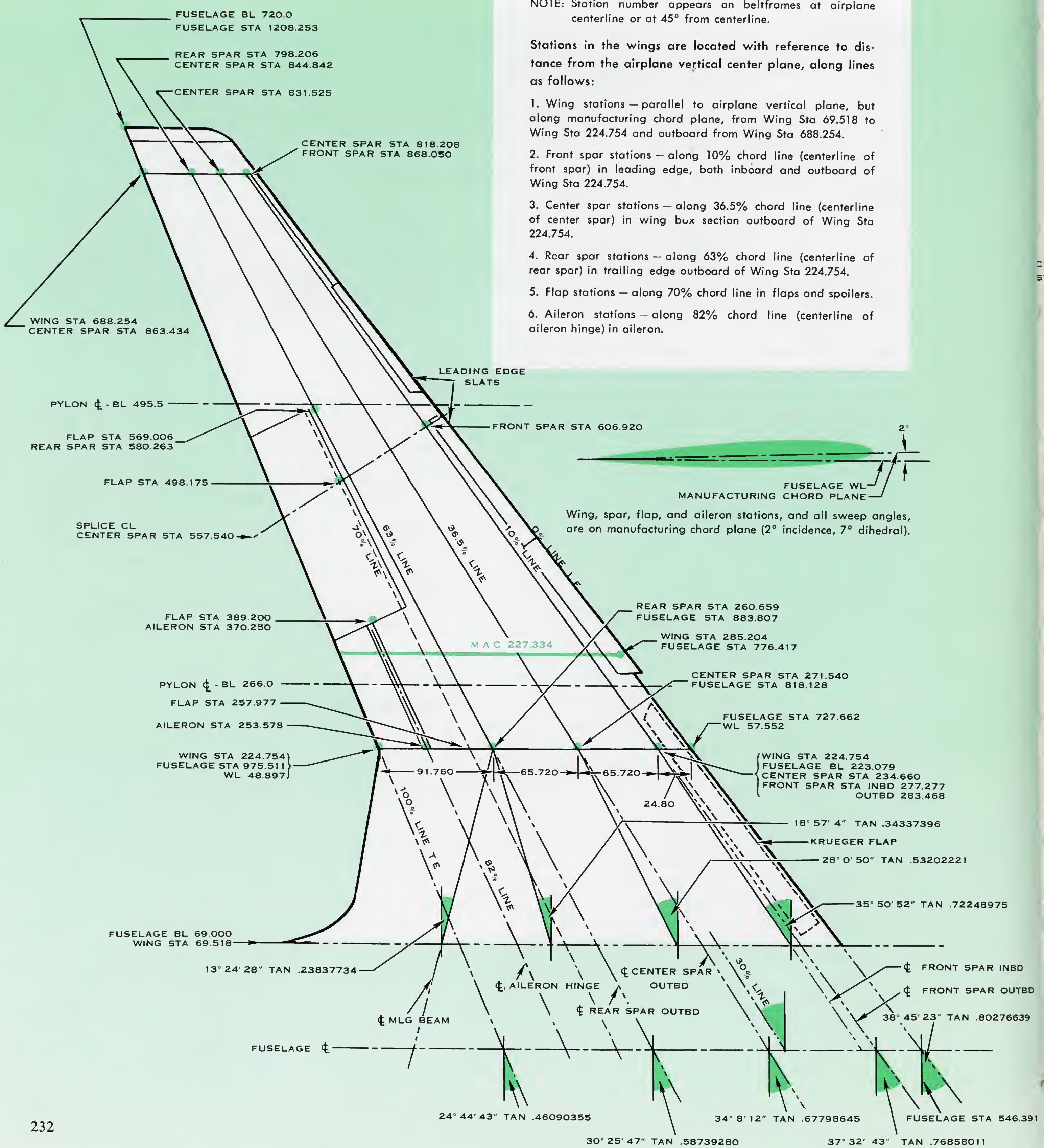
22-9 FURNISHINGS & GROUND SUPPORT
-91 Flight compartment
-92 Fwd cabin
-93 Passenger cabin
-94 Aft cabin
-95 Under-floor area
-99 Ground support equipment

880M WING STATION GEOMETRY

NOTE: Station number appears on beltframes at airplane centerline or at 45° from centerline.

Stations in the wings are located with reference to distance from the airplane vertical center plane, along lines as follows:

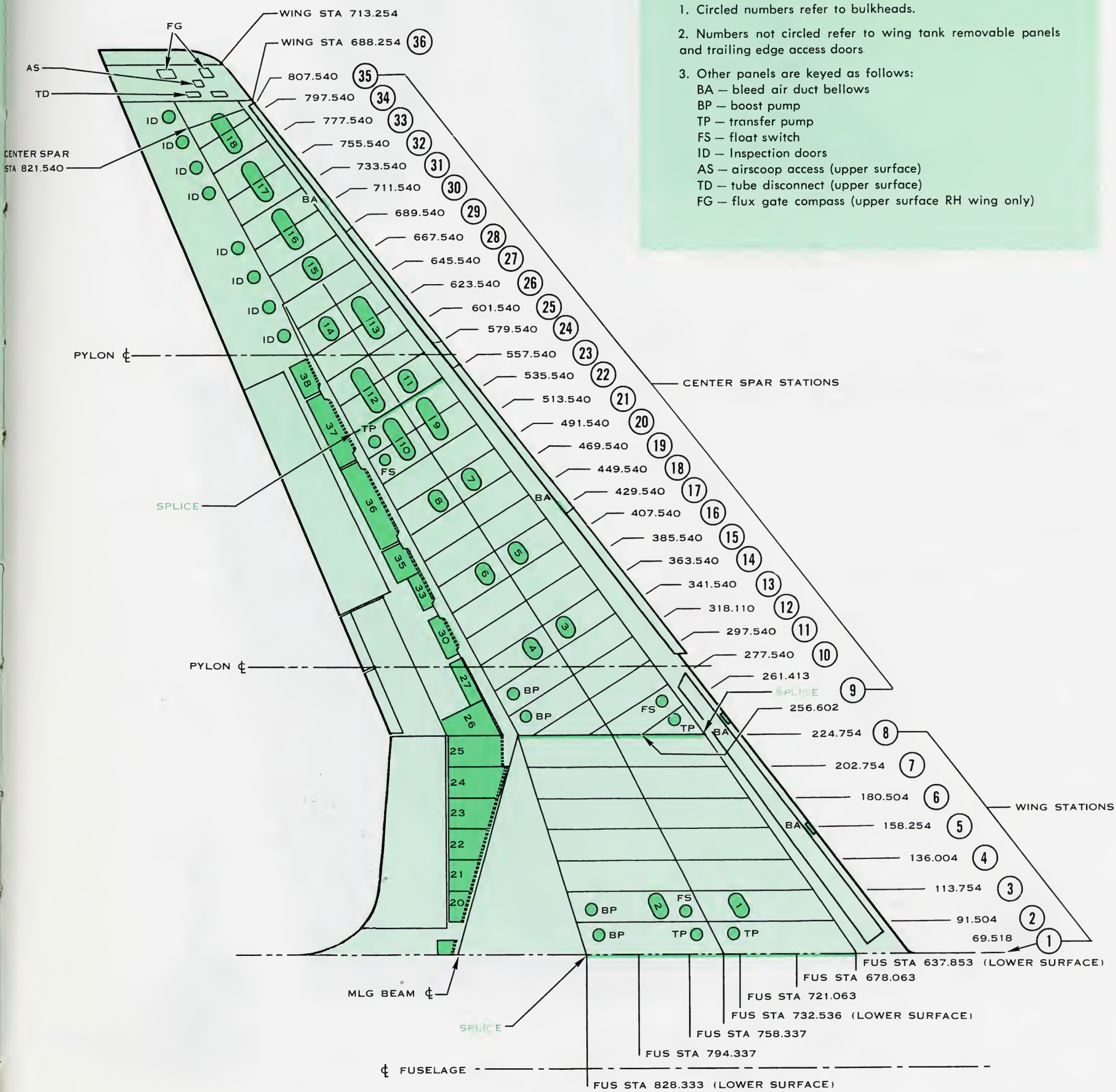
1. Wing stations — parallel to airplane vertical plane, but along manufacturing chord plane, from Wing Sta 69.518 to Wing Sta 224.754 and outboard from Wing Sta 688.254.
2. Front spar stations — along 10% chord line (centerline of front spar) in leading edge, both inboard and outboard of Wing Sta 224.754.
3. Center spar stations — along 36.5% chord line (centerline of center spar) in wing box section outboard of Wing Sta 224.754.
4. Rear spar stations — along 63% chord line (centerline of rear spar) in trailing edge outboard of Wing Sta 224.754.
5. Flap stations — along 70% chord line in flaps and spoilers.
6. Aileron stations — along 82% chord line (centerline of aileron hinge) in aileron.

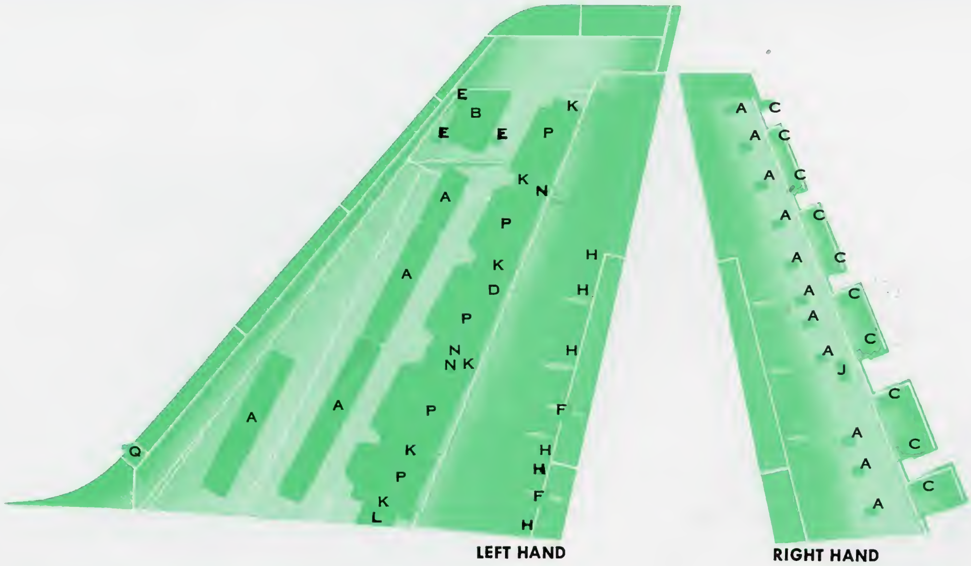


880M WING BULKHEADS AND UNDERWING ACCESS DOORS

NOTES

1. Circled numbers refer to bulkheads.
2. Numbers not circled refer to wing tank removable panels and trailing edge access doors
3. Other panels are keyed as follows:
   BA — bleed air duct bellows
   BP — boost pump
   TP — transfer pump
   FS — float switch
   ID — Inspection doors
   AS — airscoop access (upper surface)
   TD — tube disconnect (upper surface)
   FG — flux gate compass (upper surface RH wing only)

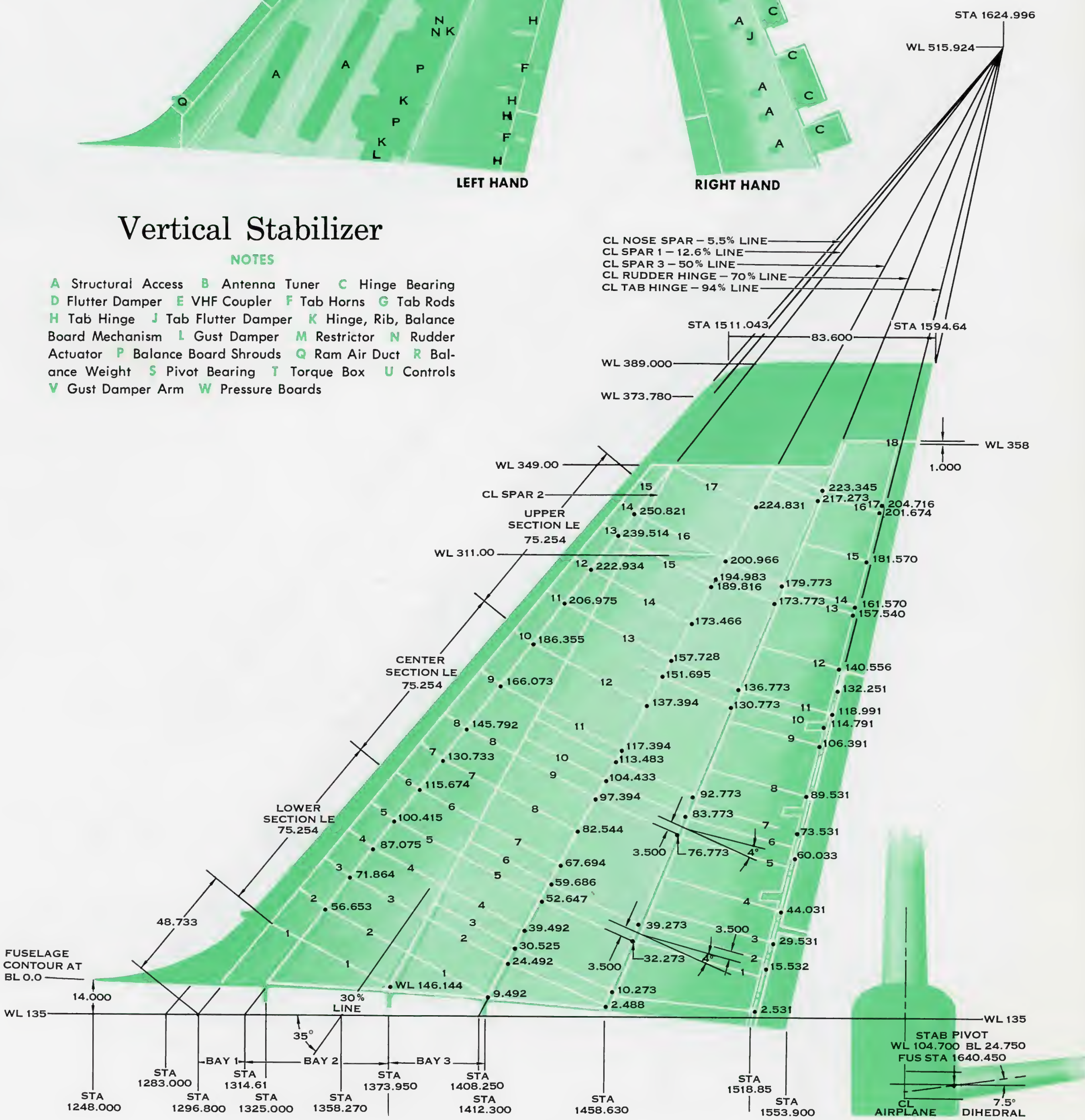


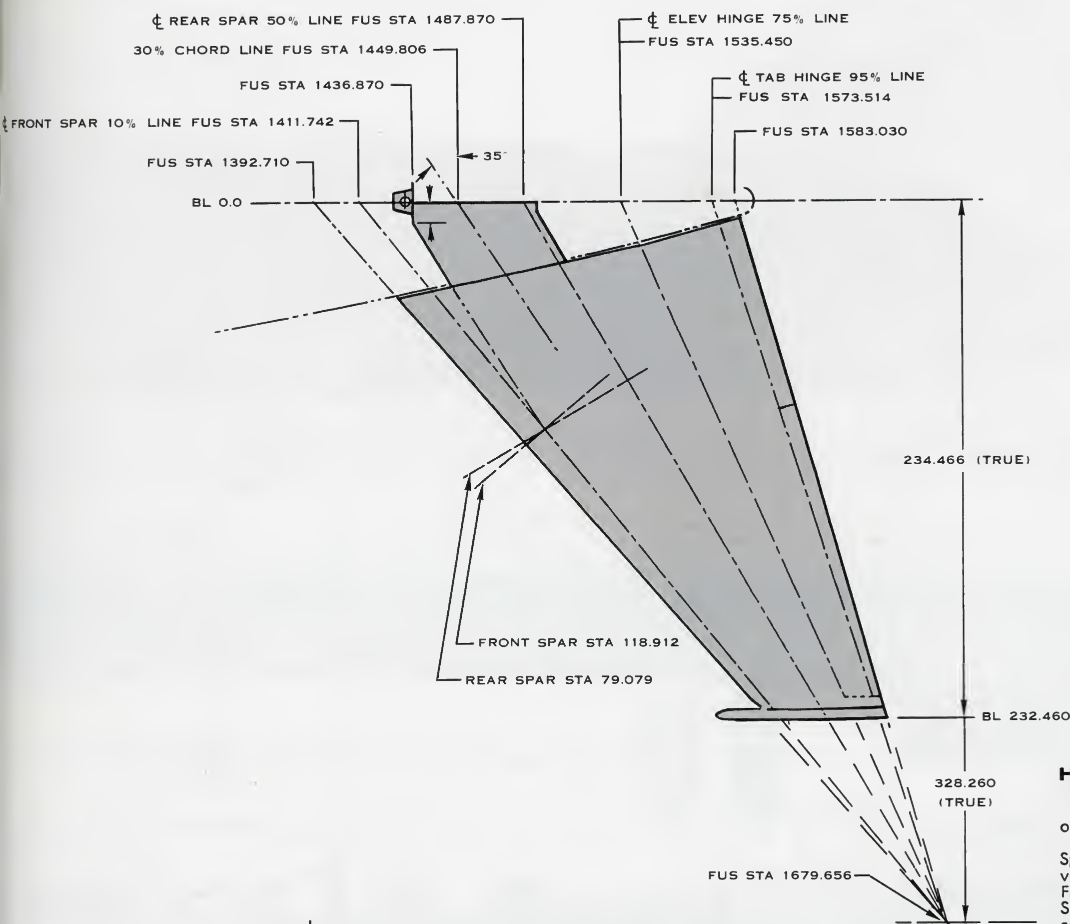


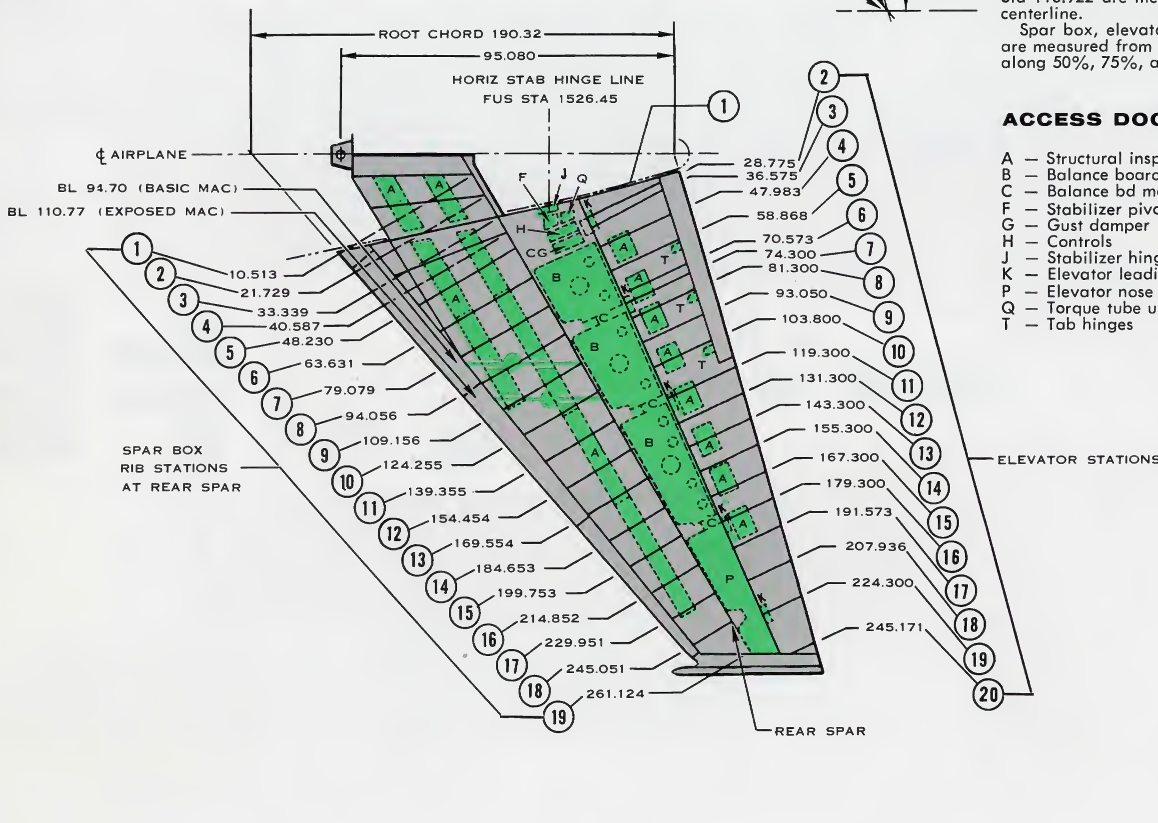
Vertical Stabilizer

NOTES

A Structural Access B Antenna Tuner C Hinge Bearing D Flutter Damper E VHF Coupler F Tab Horns G Tab Rods H Tab Hinge J Tab Flutter Damper K Hinge, Rib, Balance Board Mechanism L Gust Damper M Restrictor N Rudder Actuator P Balance Board Shrouds Q Ram Air Duct R Balance Weight S Pivot Bearing T Torque Box U Controls V Gust Damper Arm W Pressure Boards







HORIZONTAL STABILIZER

All horizontal stabilizer station dimensions are on manufacturing chord plane (7½° dihedral).

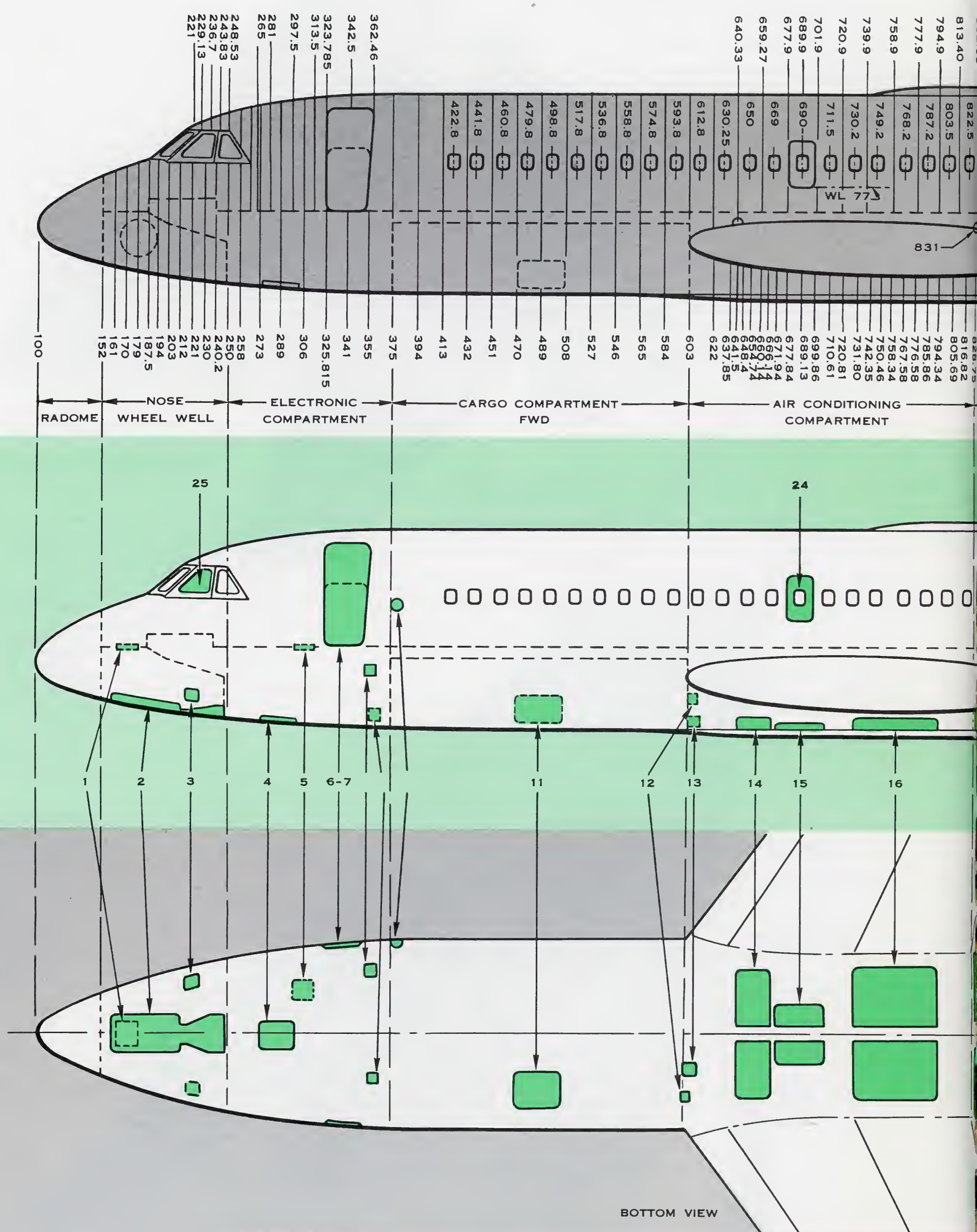
Leading edge stations outboard from Front Spar Sta 118.922 are measured from airplane vertical center plane along the 10% chord line. Front spar measurements inboard of Front Spar Sta 118.922 are measured from BL 9.078 at spar centerline.

Spar box, elevator, and trailing edge stations are measured from airplane vertical center plane along 50%, 75%, and 95% lines respectively.

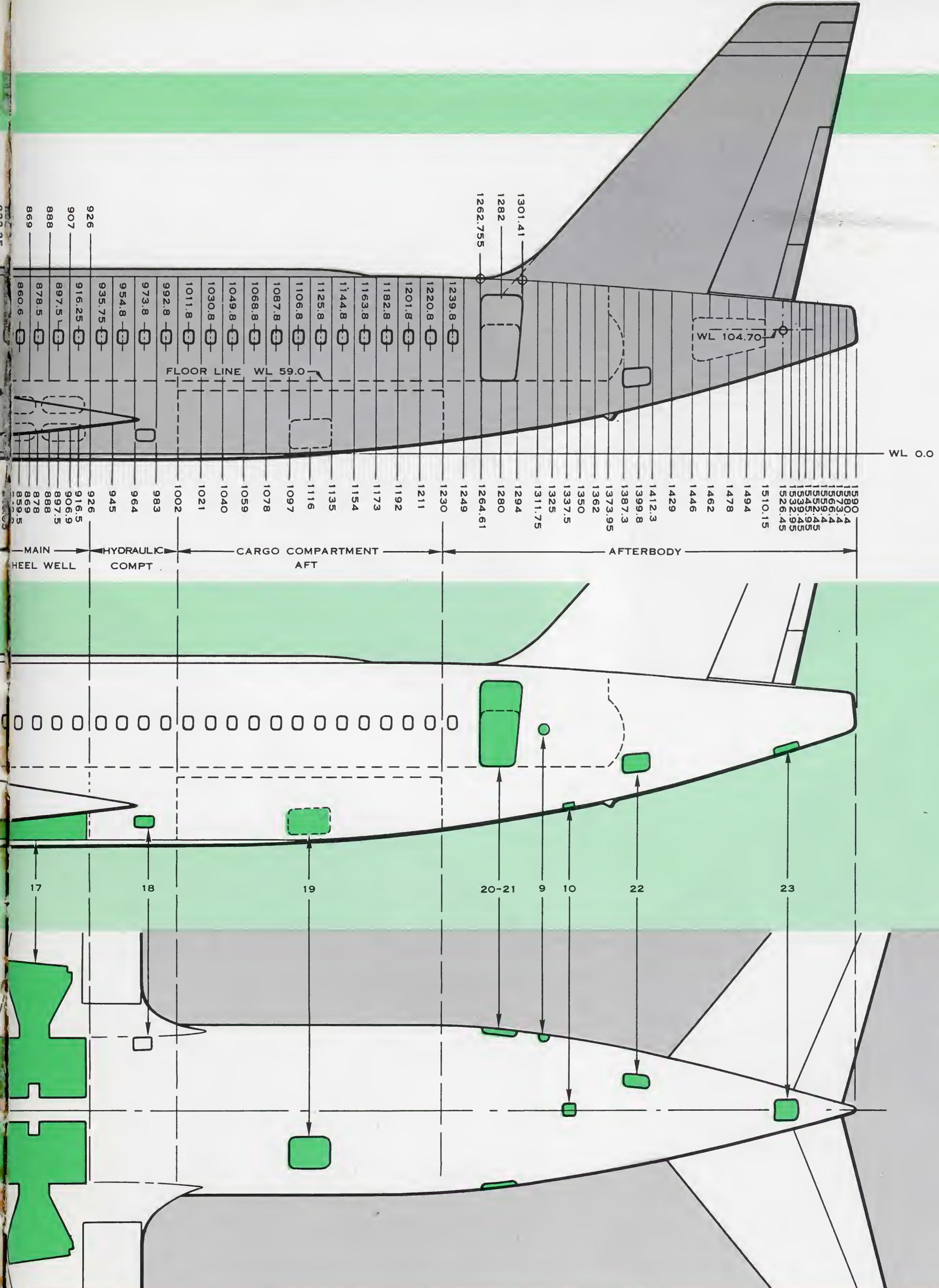
ACCESS DOORS

A — Structural inspection and access
B — Balance board shrouds
C — Balance bd mechanism, hinge support rib
F — Stabilizer pivot
G — Gust damper
H — Controls
J — Stabilizer hinge bearing
K — Elevator leading edge and hinges
P — Elevator nose
Q — Torque tube universal joint
T — Tab hinges

FUSELAGE STATIONS AND ACCESS DOORS 880M

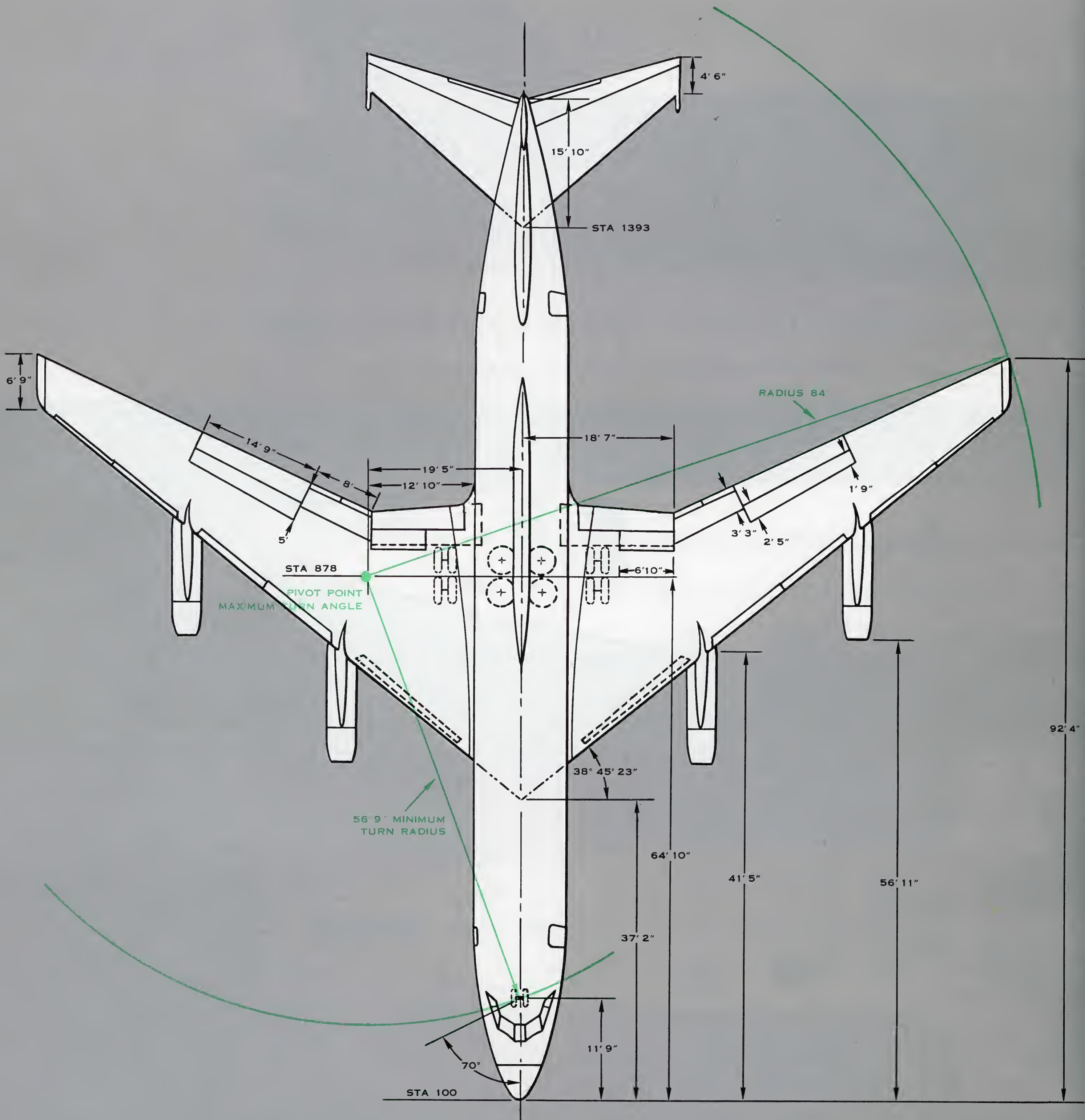


1 — Instrument panel access (from NWW)
2 — Nose wheel well
3 — Electrical compartment (LH and RH)
4 — Electrical and electronic (ground access)
5 — Electrical and electronic (in-flight access)
6 — Fwd main entrance door (LH side)
7 — Fwd service door (RH side)
8 — External AC power receptacle
9 — Loading ramp receptacle
10 — Lavatory service panel (fwd and aft)

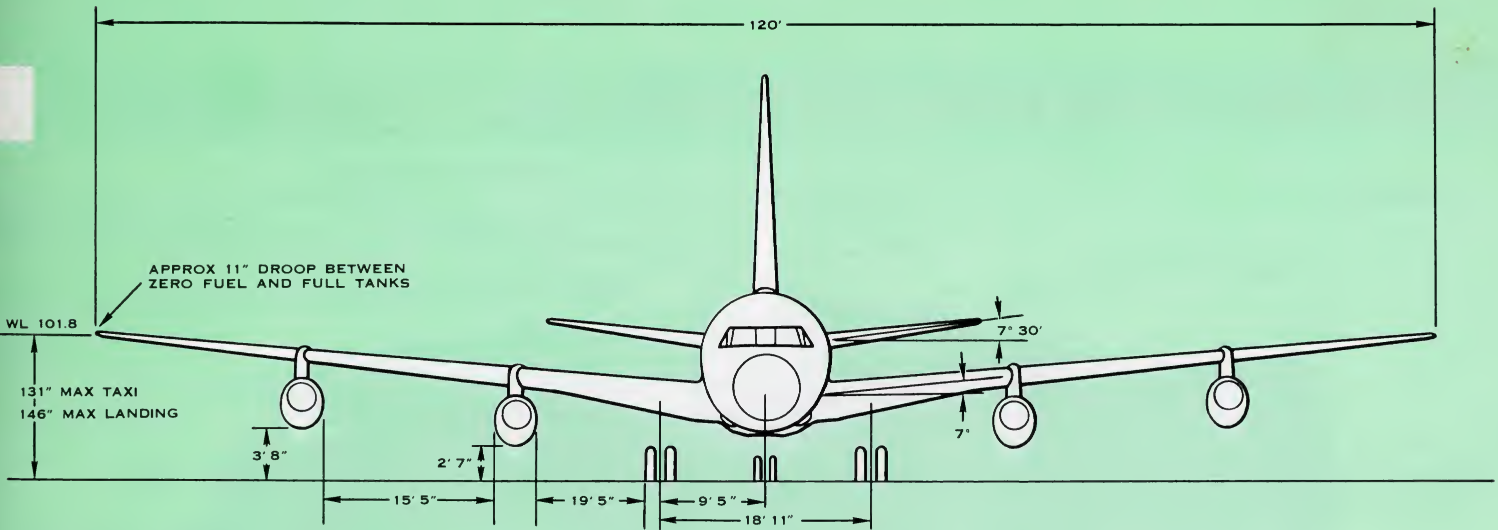


11 — Fwd cargo compartment
12 — Water service panel
13 — Ground air conditioning connection
14 — Air conditioning compressor (LH and RH)
15 — Heat exchanger (LH and RH)
16 — Freon package (LH and RH)
17 — Main wheel well
18 — Hydraulic compartment
19 — Rear cargo compartment
20 — Rear main entrance door (LH side)
21 — Rear service door (RH side)
22 — Stabilizer screwjack
23 — Aft fuselage access
24 — Cabin emergency escape door
25 — Flt compt emergency escape window

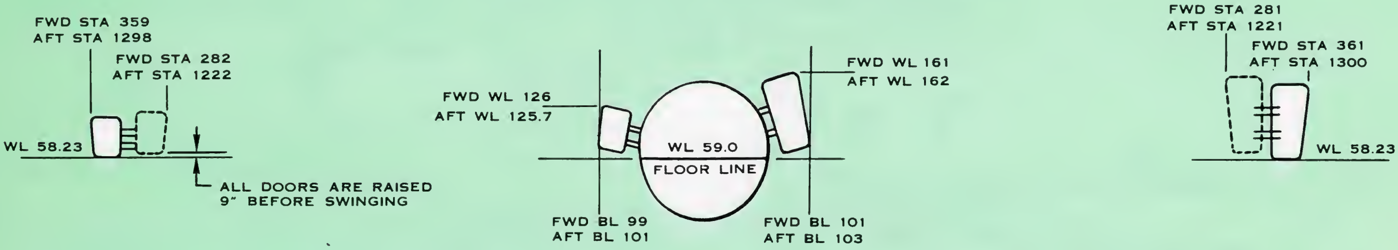
880M AIRPLANE OVERALL DIMENSIONS AND CLEARANCES



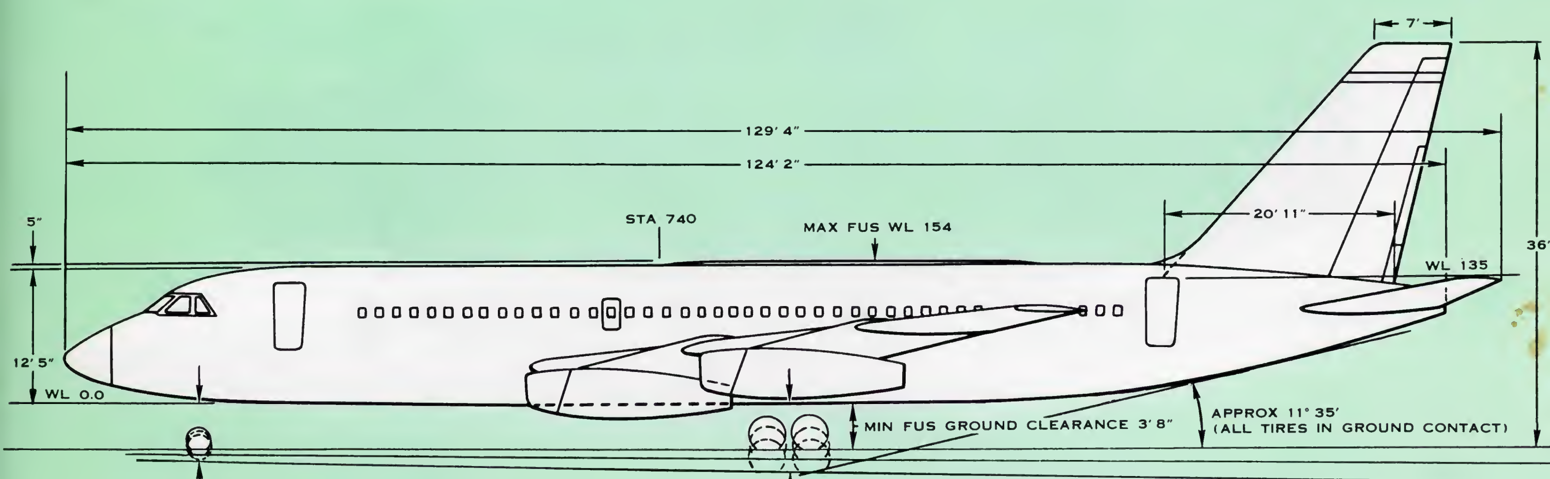
PLAN VIEW



FRONT VIEW



DOOR CLEARANCES



CG MOST FWD	CG MOST AFT		CG MOST FWD	CG MOST AFT
52"	55"	MAXIMUM TAXI WEIGHT 193,500 LB	50"	49"
53"	59"	MAXIMUM LANDING WEIGHT 155,000 LB	50"	50"
54"	61"	ZERO FUEL WEIGHT 121,500 LB	52"	51"

SIDE VIEW

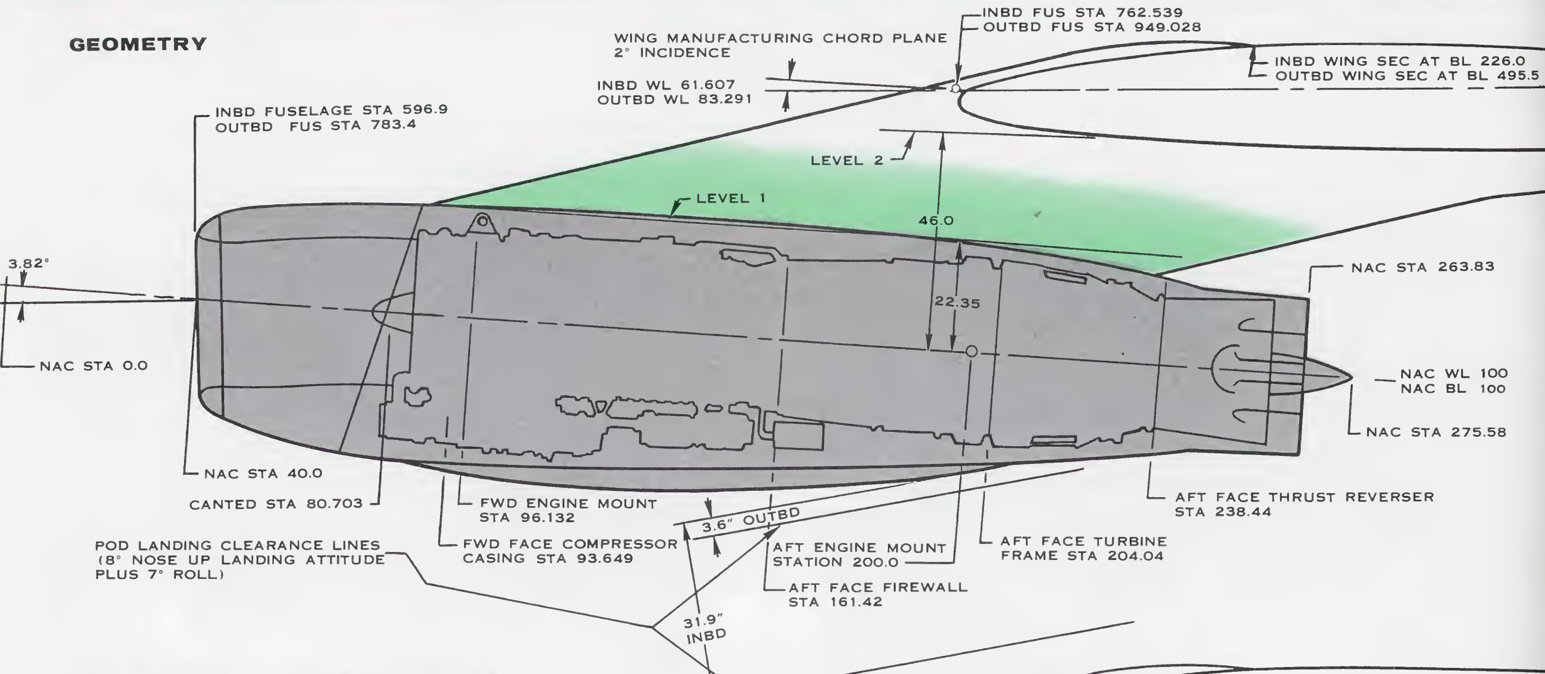
NOTES

All dimensions and stations on pages 238 and 239 are to nearest inch only. Stations are fuselage stations, measured from 100 inches forward of the airplane nose.

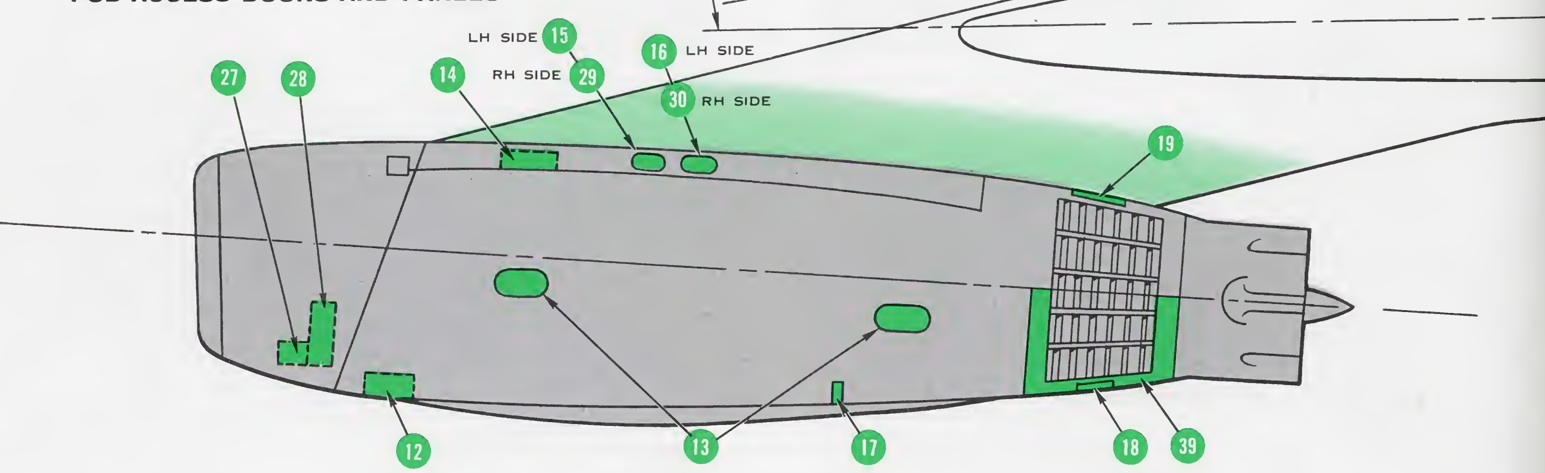
Heights from ground are with airplane fully loaded and fueled, 193,500 lb maximum taxi weight, nominal center of gravity.

PODS AND PYLONS 880M

GEOMETRY



POD ACCESS DOORS AND PANELS

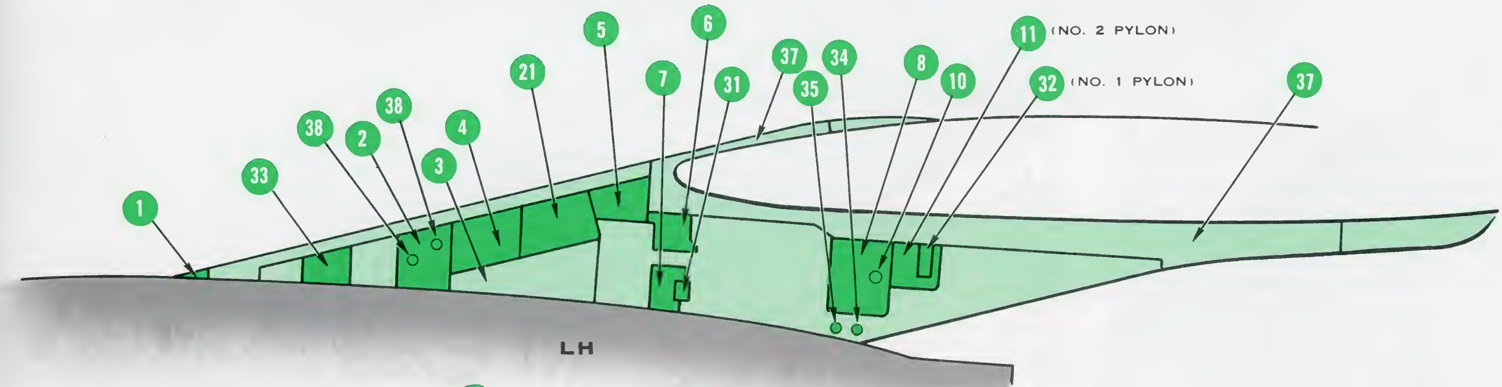


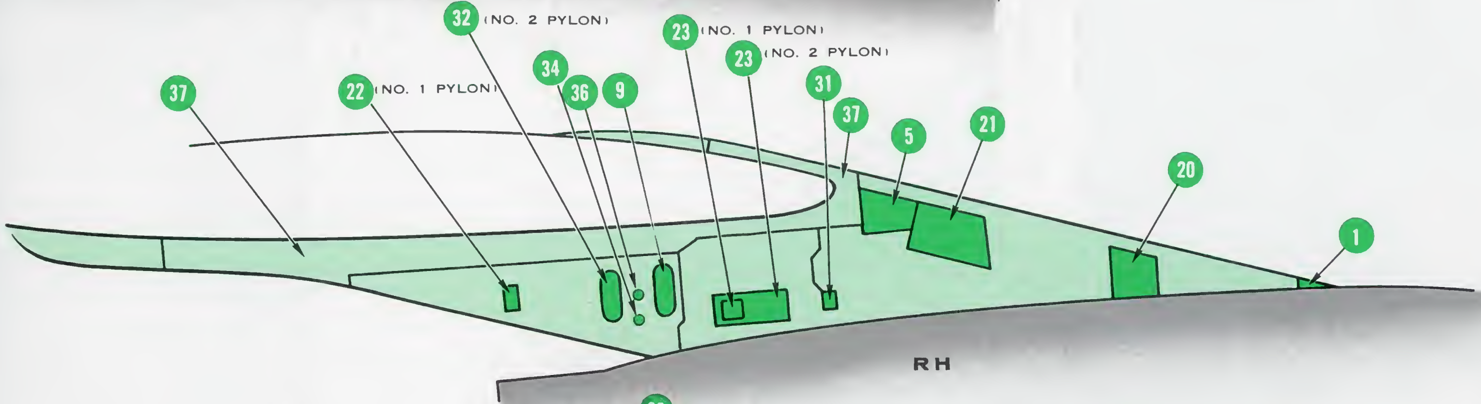
POD AND PYLON ACCESS PANELS, SERVICE POINTS, AND DRAINS

1 Hoist lug
2 Hydraulic filters
3 Bleed air regulator
4 Fluid and electrical lines
5 Power control unit
6 Fluid lines
7 Fire ext. check valve and bleed air duct
8 Fire bottle removal (large panel)
9 Fire bottle removal (small panel)
10 Fire bottle pressure gage
11 Refuel panel
12 Engine ground start (inbd pod or pods)
13 Engine fire access
14 Oil gravity fill
15 Fluid lines and door hinge
16 Fluid lines and door hinge
17 Fuel drain tank ground drain
18 Rigging door, thrust reverser
19 Rigging door, thrust reverser
20 Fluid and electrical lines
21 Fluid and electrical lines
22 Interphone jack
23 Structural inspection
27 Anti-icing valve
28 Vortex destroyer valve
29 Electrical and door hinge
30 Electrical and door hinge
31 Hoist attach
32 Fire detector control units
33 Oil tank access
34 Fire extinguisher line drain
35 Frangible blowout disc, fire bottle
36 Fuel tank drain
37 Pylon draft seal removable panels
38 Hydraulic filter view holes
39 Removable tail cowl

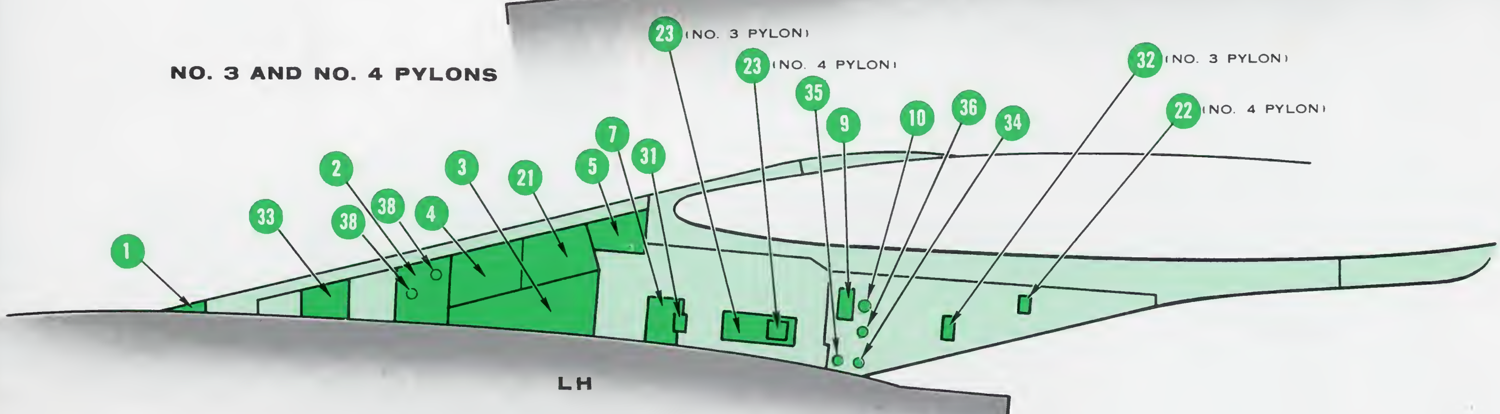
PYLON ACCESS PANELS 880M

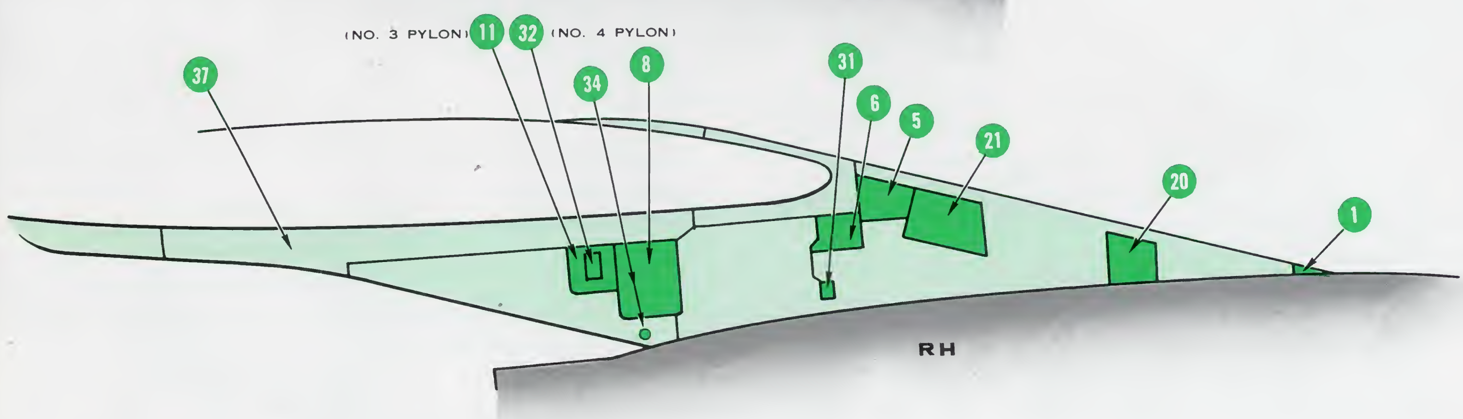
NO. 1 AND NO. 2 PYLONS

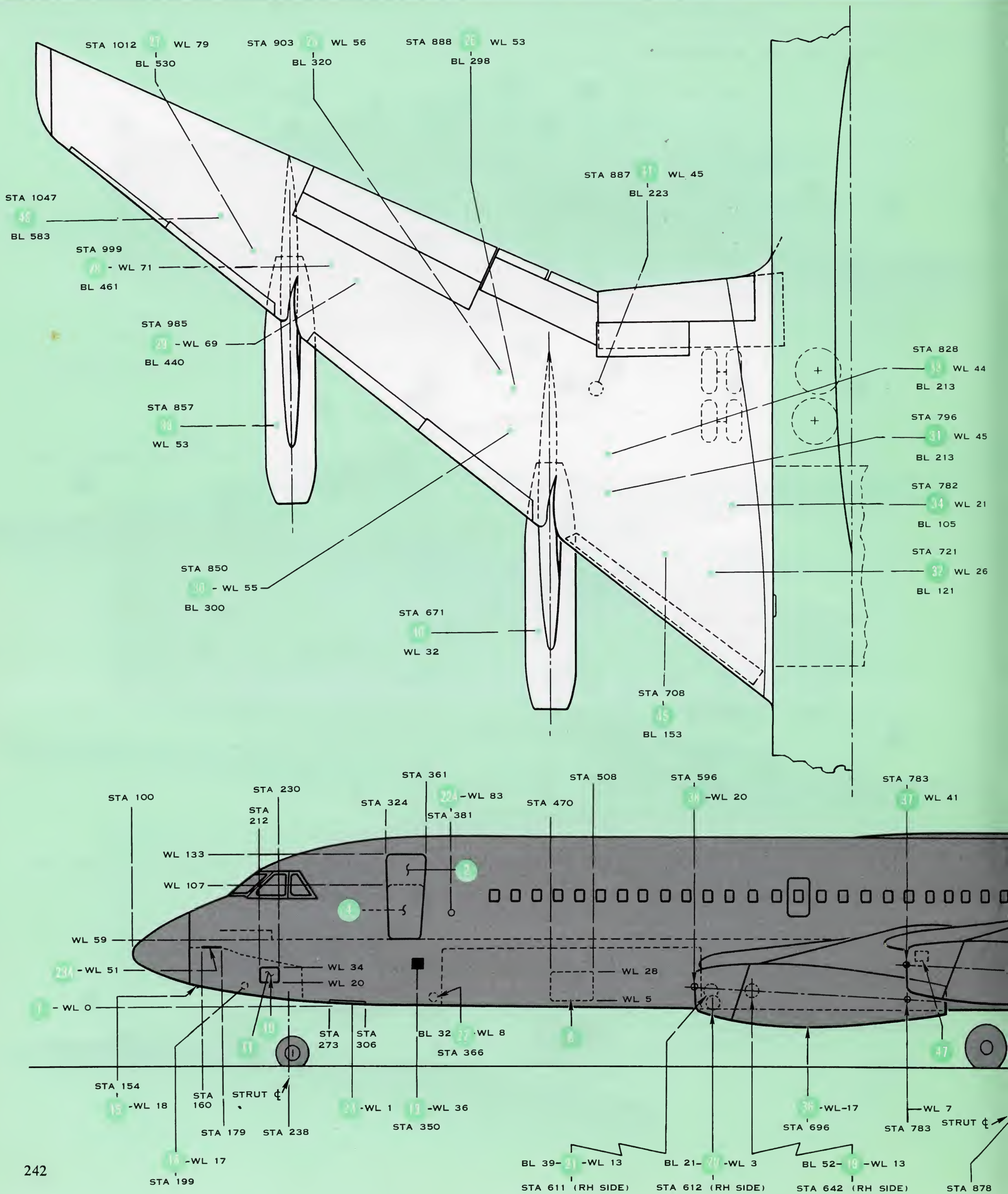




NO. 3 AND NO. 4 PYLONS



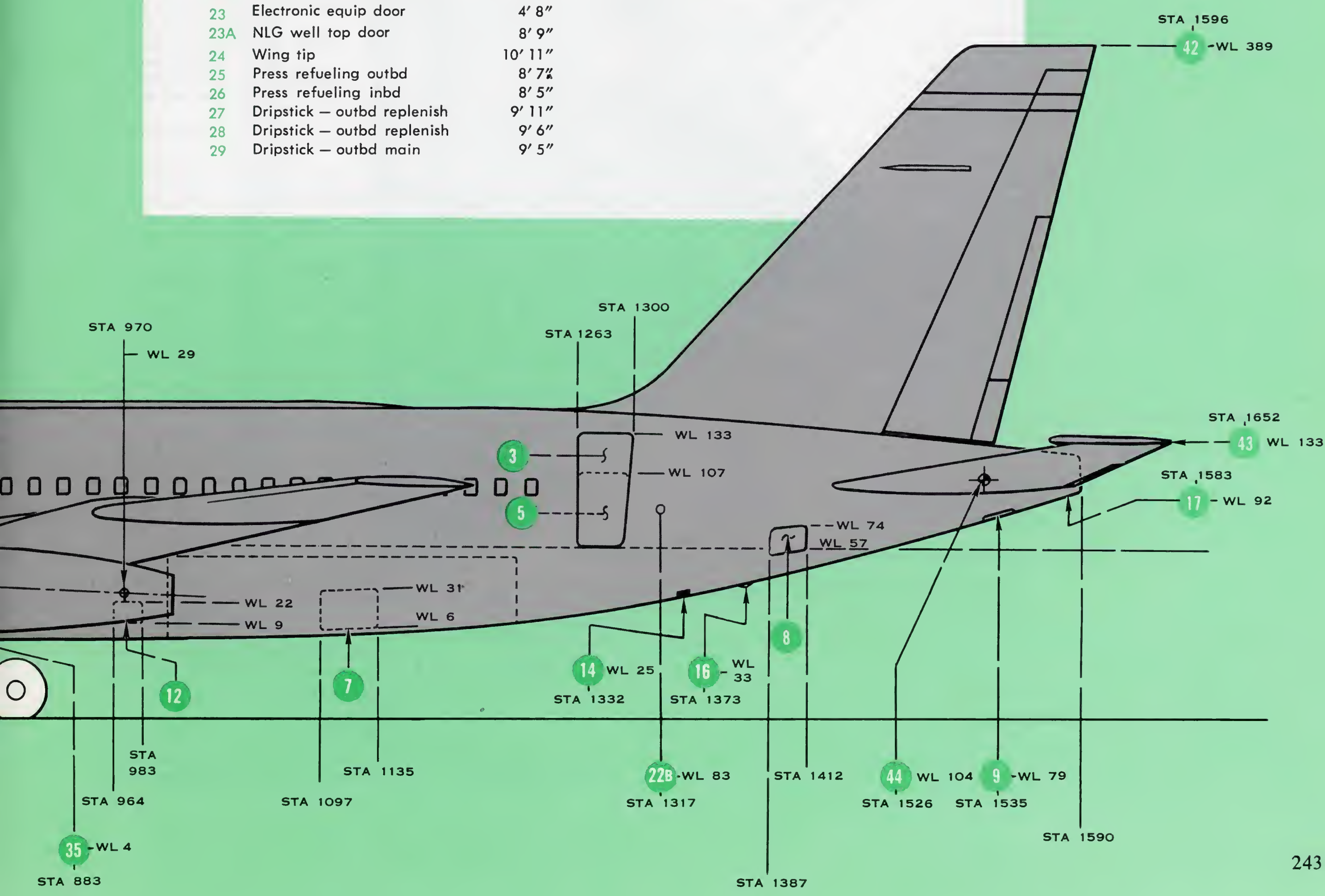



STA 1012 WL 79 BL 530
STA 903 WL 56 BL 320
STA 888 WL 53 BL 298
STA 887 WL 45 BL 223
STA 1047 BL 583
STA 999 WL 71 BL 461
STA 985 WL 69 BL 440
STA 857 WL 53
STA 828 WL 44 BL 213
STA 796 WL 45 BL 213
STA 782 WL 21 BL 105
STA 721 WL 26 BL 121
STA 850 WL 55 BL 300
STA 671 WL 32
STA 708 BL 153
STA 100
STA 230
STA 212
STA 361 WL 83
STA 324
STA 381
STA 508
STA 470
STA 596 WL 20
STA 783 WL 41
WL 133
WL 107
WL 59
WL 51
WL 0
WL 34
WL 20
WL 28
WL 5
STA 273
STA 306
BL 32 WL 8
STA 366
STA 154 WL 18
STA 160
STRUT ¢
STA 179
STA 238
WL 1
WL 36
STA 350
WL-17
STA 696
WL 7
STA 783
STRUT ¢
WL 17
STA 199
BL 39- WL 13
STA 611 (RH SIDE)
BL 21- WL 3
STA 612 (RH SIDE)
BL 52- WL 13
STA 642 (RH SIDE)
STA 878

APPROXIMATE HEIGHTS FROM GROUND AT MAXIMUM TAXI WEIGHT

1	Fuselage	3′ 8″
2	Main entrance door — fwd	9′ 6″
3	Main entrance door — aft	9′
4	Service door — fwd	9′ 6″
5	Service door — aft	9′
6	Cargo door — fwd	4′ 9″
7	Cargo door — aft	4′ 7″
8	Tail cone door — fwd	8′ 8″
9	Tail cone door — aft	10′ 6″
10	Elec equip door — LH	6′ 4″
11	Elec equip door — RH	6′ 4″
12	Hydraulic door	4′ 11″
13	Lavatory service panel — fwd	7′ 6″
14	Lavatory service panel — aft	6′
15	Jack point — fuselage	6′ 2″
16	Tail skid	6′ 10″
17	Tail cone	11′ 2″
18	Pneumatic air Model 22-2	6′
19	Pneumatic air Model 22-1	5′ 5″
20	Preconditioned air	4′ 8″
21	Water filler access	5′ 6″
22	External power receptacle	5′ 3″
22A	Loading ramp recept — fwd	11′ 5″
22B	Loading ramp recept — aft	11′ 2″
23	Electronic equip door	4′ 8″
23A	NLG well top door	8′ 9″
24	Wing tip	10′ 11″
25	Press refueling outbd	8′ 7″
26	Press refueling inbd	8′ 5″
27	Dripstick — outbd replenish	9′ 11″
28	Dripstick — outbd replenish	9′ 6″
29	Dripstick — outbd main	9′ 5″
30	Dripstick — outbd main	8′ 7″
31	Dripstick — inbd replenish	7′ 11″
32	Dripstick — inbd replenish	6′ 6″
33	Dripstick — inbd main	7′ 10″
34	Dripstick — inbd main	6′
35	Engine pod — outbd	3′ 10″
36	Engine pod — inbd	2′ 8″
37	Engine CL fwd end outbd	7′
38	Engine CL fwd end inbd	5′ 10″
39	Oil filler caps outbd	8′
40	Oil filler caps inbd	6′ 10″
41	Jack points — wing	7′ 10″
42	Vertical stabilizer tip	36′
43	Horizontal stabilizer tip	14′ 8″
44	Horizontal stab pivot point	12 6″
45	Gravity fill refueling inbd	9′ 6″
46	Gravity fill refueling outbd	12′
47	Refuel panel inbd pylons	7′ 8″

NOTES: Door dimensions refer to door sill elevations. All dimensions, stations, buttock lines and waterlines are to nearest inch.



990 WING STATION GEOMETRY

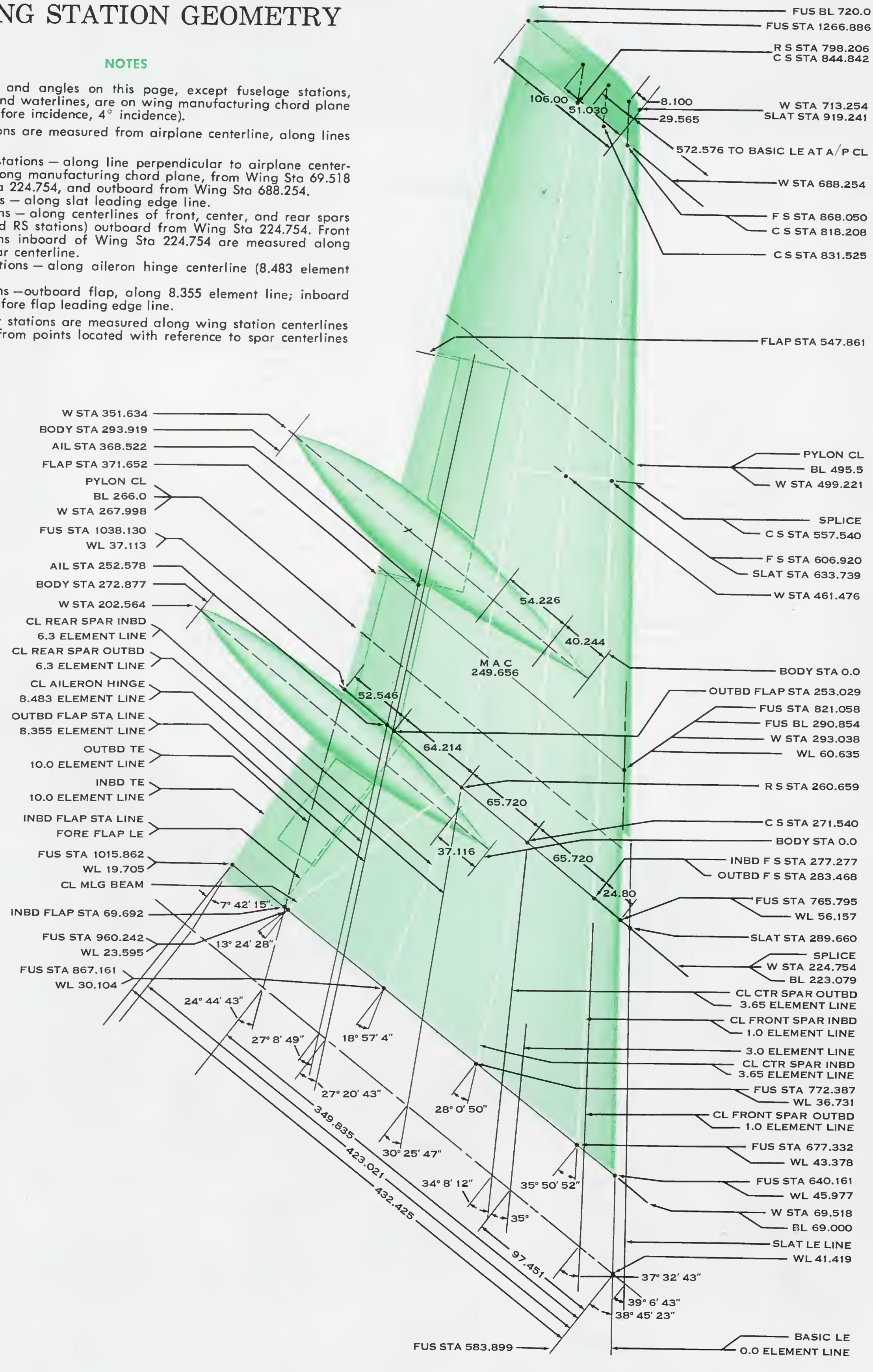
NOTES

All dimensions and angles on this page, except fuselage stations, buttock lines, and waterlines, are on wing manufacturing chord plane (7° dihedral before incidence, 4° incidence).

Structural stations are measured from airplane centerline, along lines as follows:

1 Wing (W) stations — along line perpendicular to airplane centerline, but along manufacturing chord plane, from Wing Sta 69.518 to Wing Sta 224.754, and outboard from Wing Sta 688.254.
2 Slat stations — along slat leading edge line.
3 Spar stations — along centerlines of front, center, and rear spars (FS, CS, and RS stations) outboard from Wing Sta 224.754. Front spar stations inboard of Wing Sta 224.754 are measured along inboard spar centerline.
4 Aileron stations — along aileron hinge centerline (8.483 element line).
5 Flap stations — outboard flap, along 8.355 element line; inboard flap, along fore flap leading edge line.

Anti-shock body stations are measured along wing station centerlines of the bodies, from points located with reference to spar centerlines as shown.

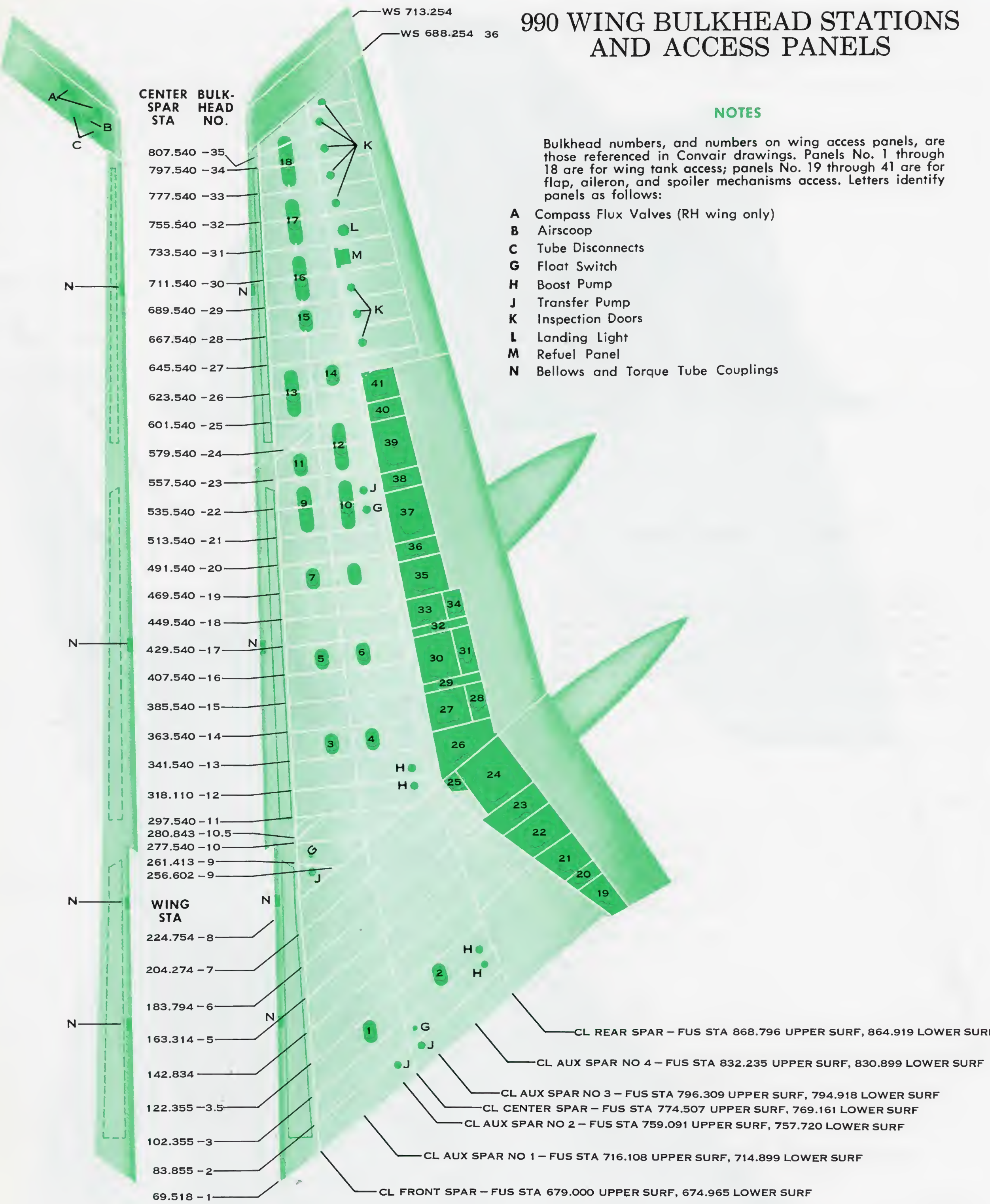


990 WING BULKHEAD STATIONS AND ACCESS PANELS

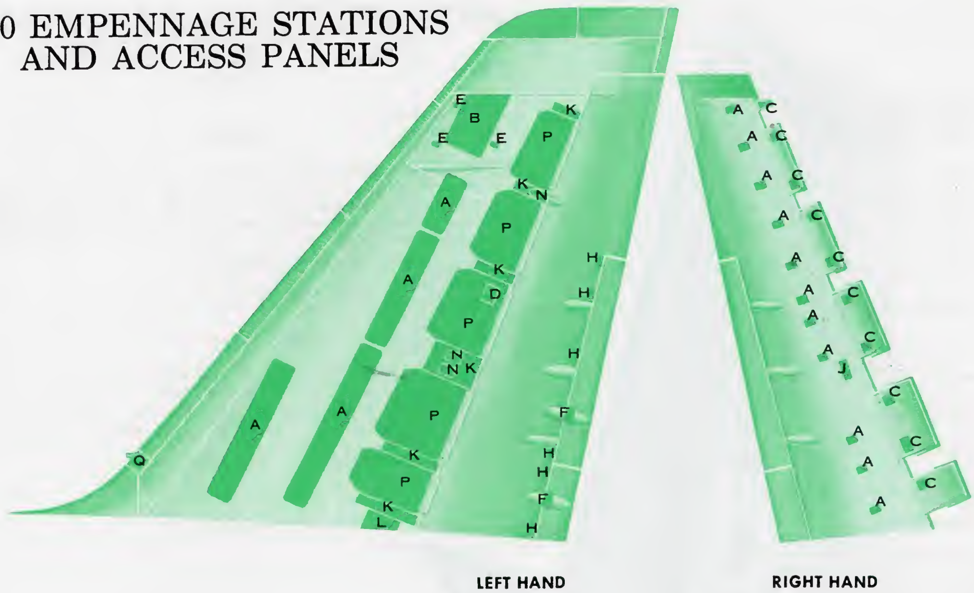
NOTES

Bulkhead numbers, and numbers on wing access panels, are those referenced in Convair drawings. Panels No. 1 through 18 are for wing tank access; panels No. 19 through 41 are for flap, aileron, and spoiler mechanisms access. Letters identify panels as follows:

- **A** Compass Flux Valves (RH wing only)
- **B** Airscoop
- **C** Tube Disconnects
- **G** Float Switch
- **H** Boost Pump
- **J** Transfer Pump
- **K** Inspection Doors
- **L** Landing Light
- **M** Refuel Panel
- **N** Bellows and Torque Tube Couplings



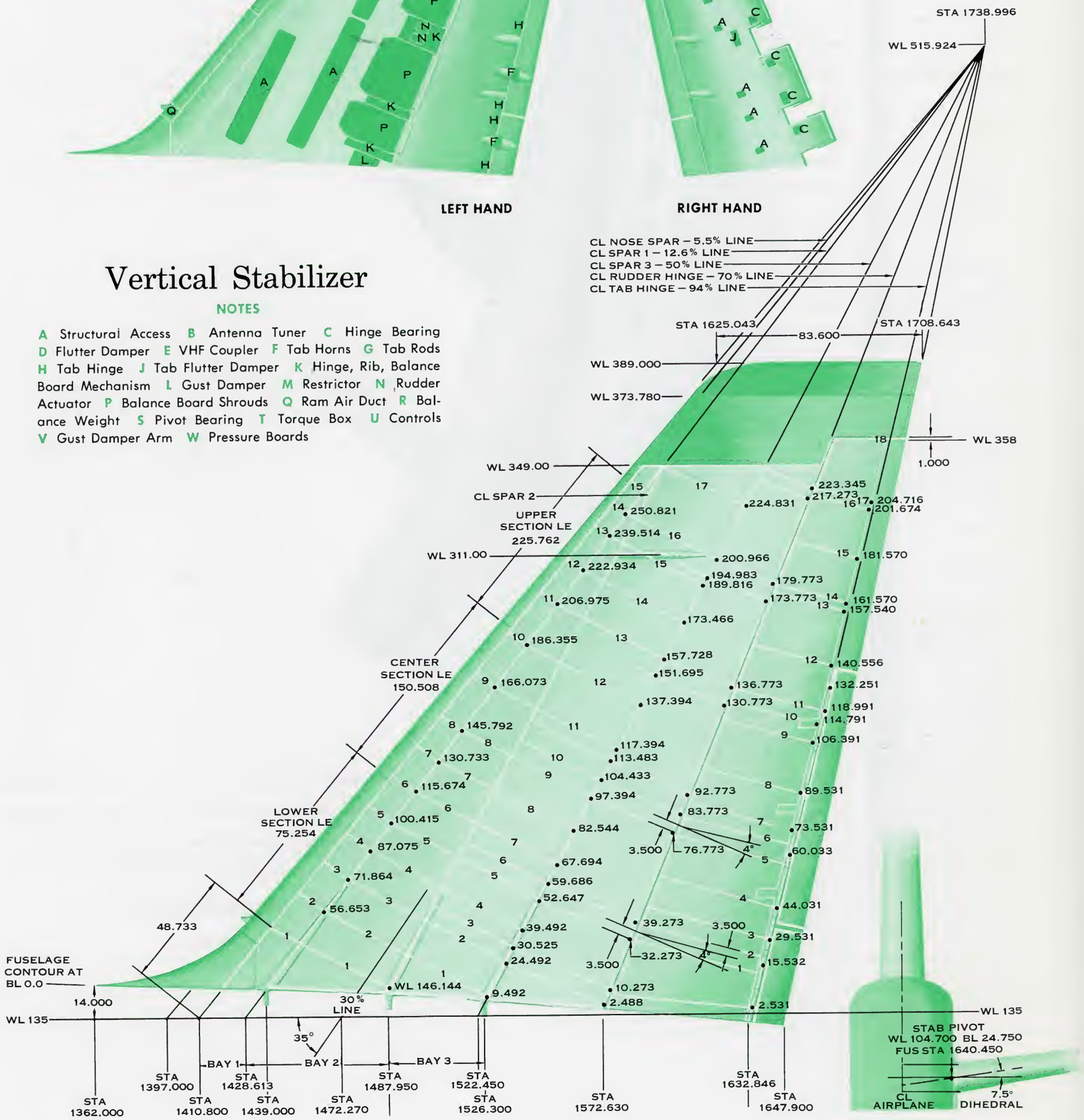
990 EMPENNAGE STATIONS AND ACCESS PANELS

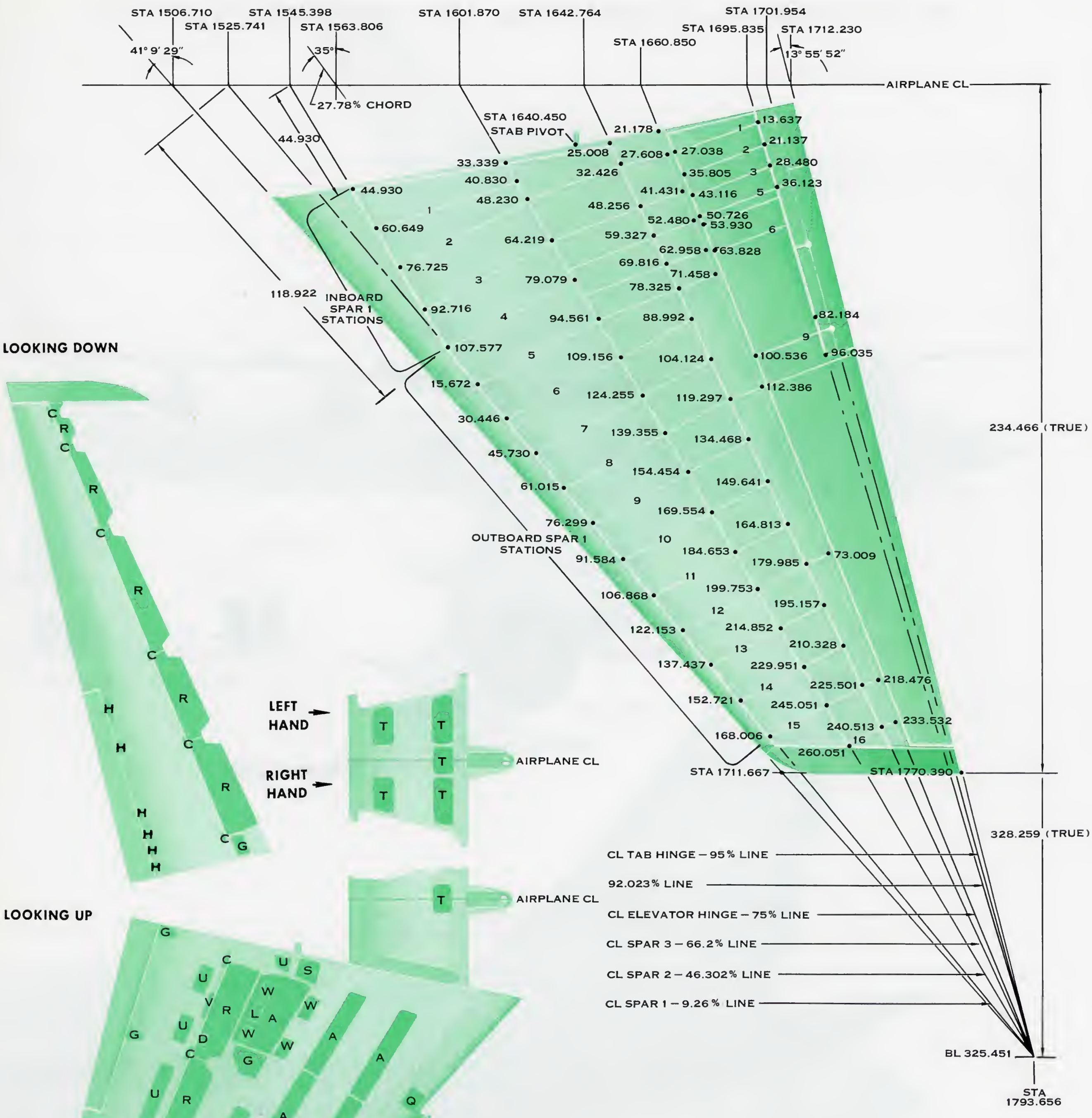


Vertical Stabilizer

NOTES

A Structural Access B Antenna Tuner C Hinge Bearing D Flutter Damper E VHF Coupler F Tab Horns G Tab Rods H Tab Hinge J Tab Flutter Damper K Hinge, Rib, Balance Board Mechanism L Gust Damper M Restrictor N Rudder Actuator P Balance Board Shrouds Q Ram Air Duct R Balance Weight S Pivot Bearing T Torque Box U Controls V Gust Damper Arm W Pressure Boards





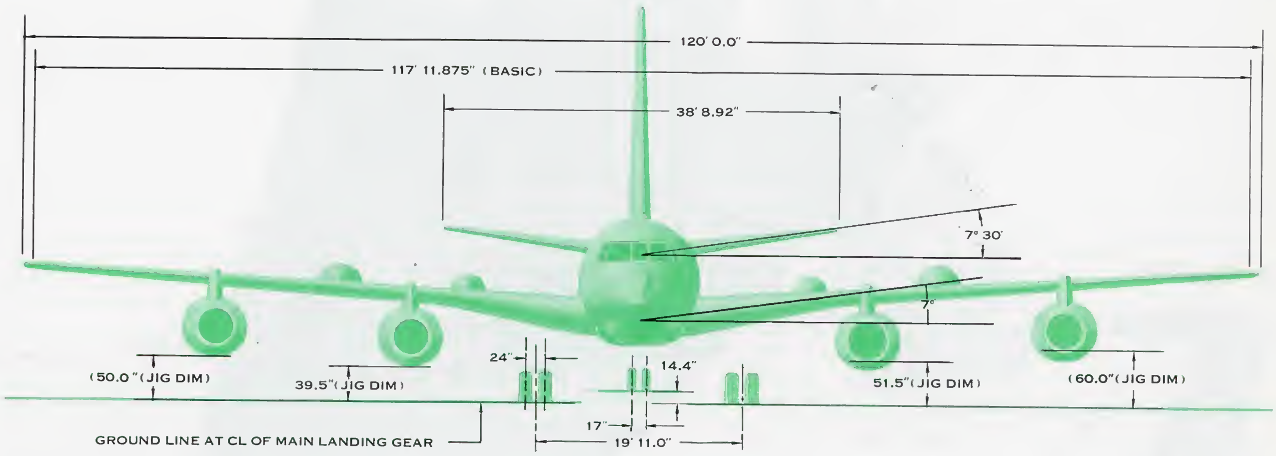
Horizontal Stabilizer

NOTES

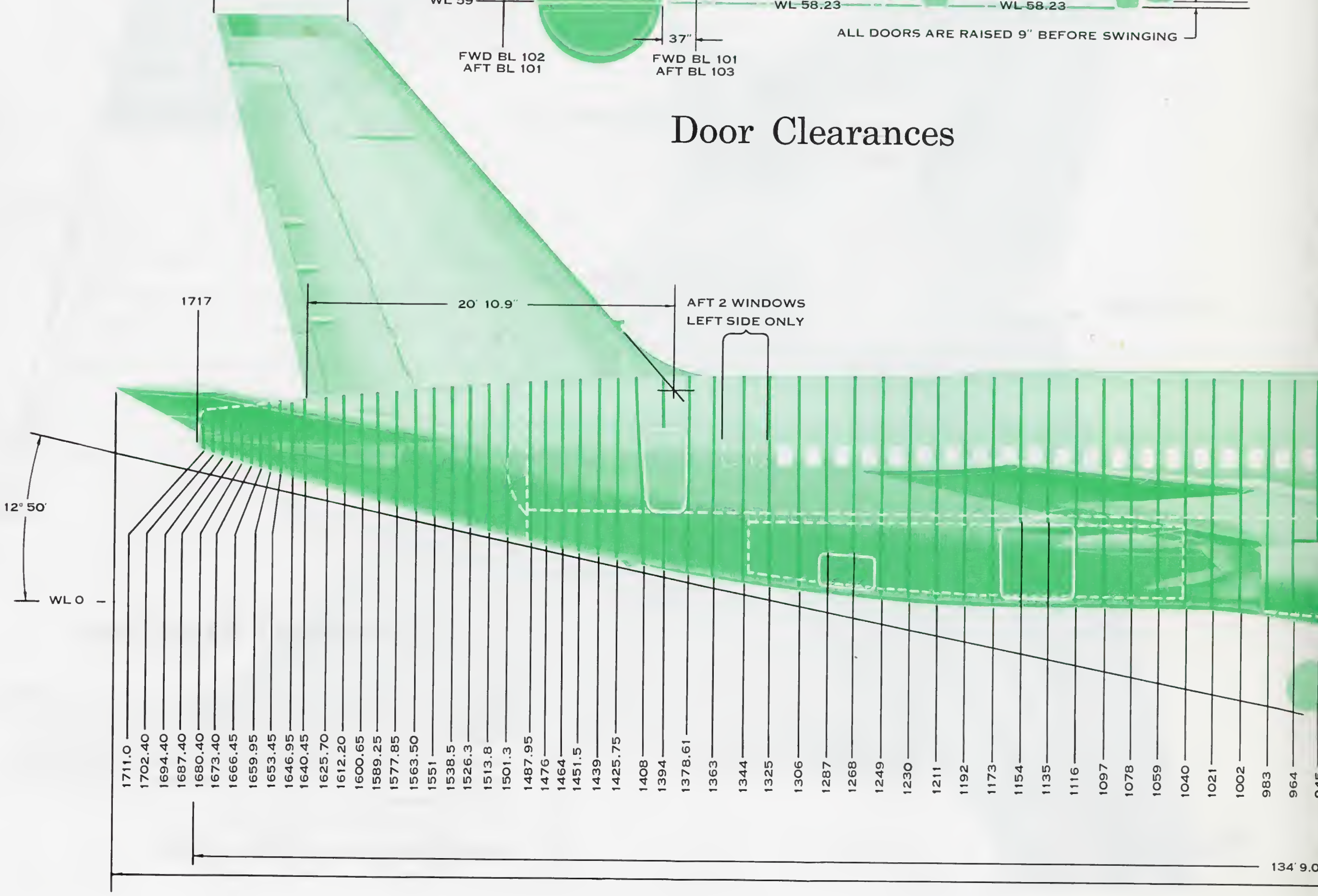
Vertical and horizontal stabilizer stations are measured from WL 135.0 and from airplane centerline, along spar and hinge centerlines; except that leading edge stations are usually measured from the points indicated. All horizontal stabilizer angles and stations are on the manufacturing chord plane (7½° dihedral).

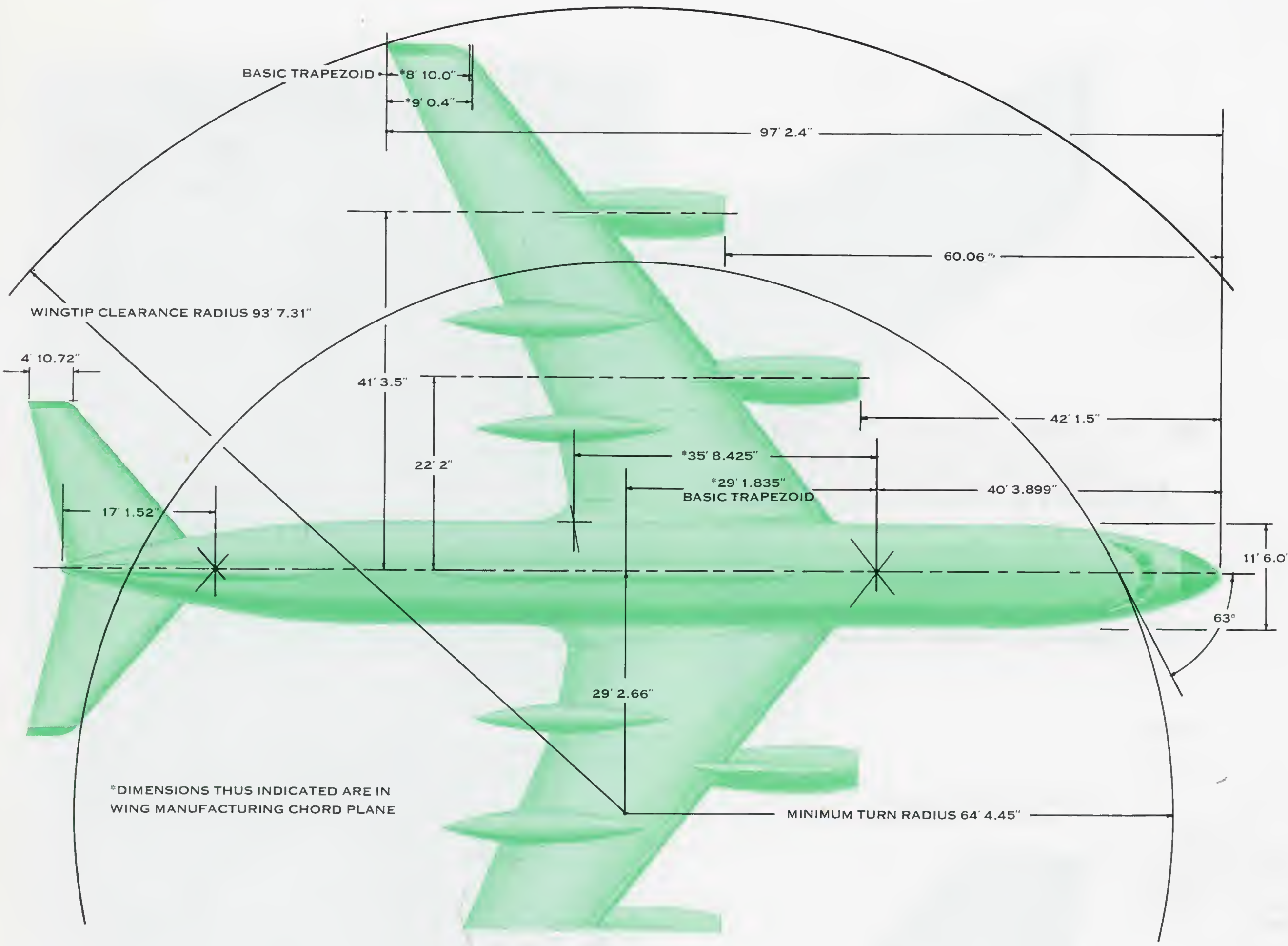
Ribs are numbered as in Convair drawings.

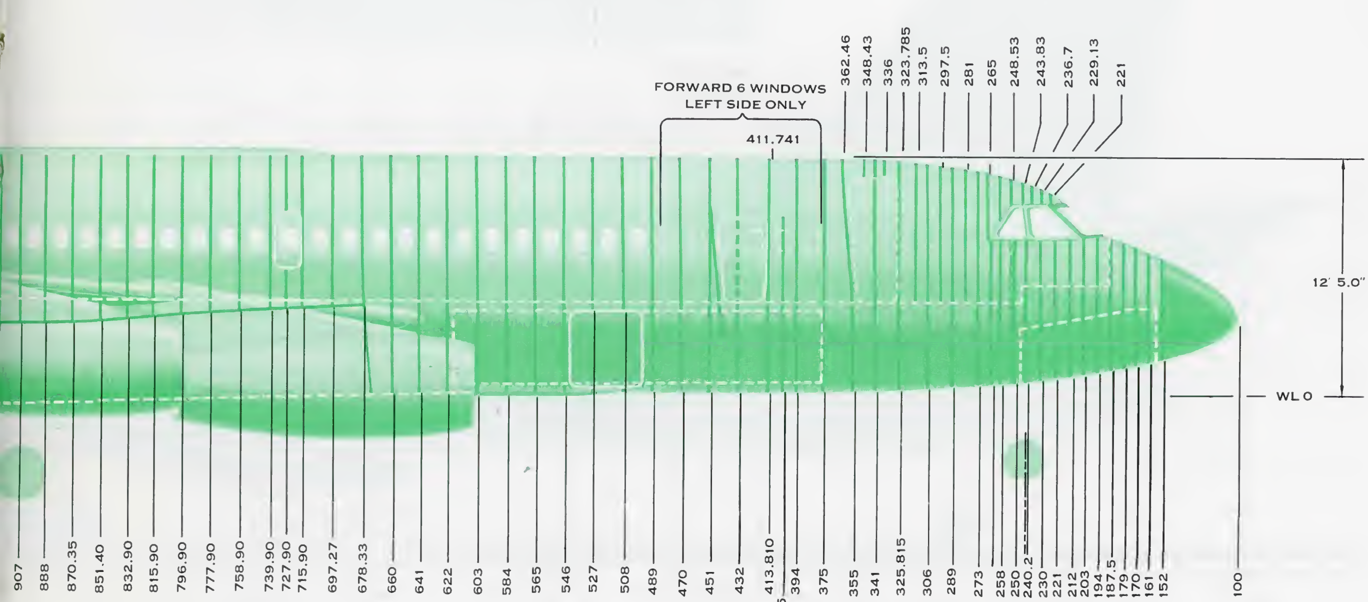
990 DIMENSIONS, CLEARANCES, AND FUSELAGE STATIONS



Door Clearances




BASIC TRAPEZOID
*8' 10.0"
*9' 0.4"
97' 2.4"
60.06"
WINGTIP CLEARANCE RADIUS 93' 7.31"
4' 10.72"
41' 3.5"
42' 1.5"
*35' 8.425"
22' 2"
*29' 1.835"
BASIC TRAPEZOID
40' 3.899"
17' 1.52"
11' 6.0"
63°
29' 2.66"
*DIMENSIONS THUS INDICATED ARE IN
WING MANUFACTURING CHORD PLANE
MINIMUM TURN RADIUS 64' 4.45"


FORWARD 6 WINDOWS
LEFT SIDE ONLY
411.741
362.46
348.43
336
323.785
313.5
297.5
281
265
248.53
243.83
236.7
229.13
221
12' 5.0"
WL 0
907
888
870.35
851.40
832.90
815.90
796.90
777.90
758.90
739.90
727.90
715.90
697.27
678.33
660
641
622
603
584
565
546
527
508
489
470
451
432
413.810
401.5
394
375
355
341
325.815
306
289
273
258
250
240.2
230
221
212
203
194
187.5
179
170
161
152
100
57' 2.34"
11' 8.16"
139' 2.4"

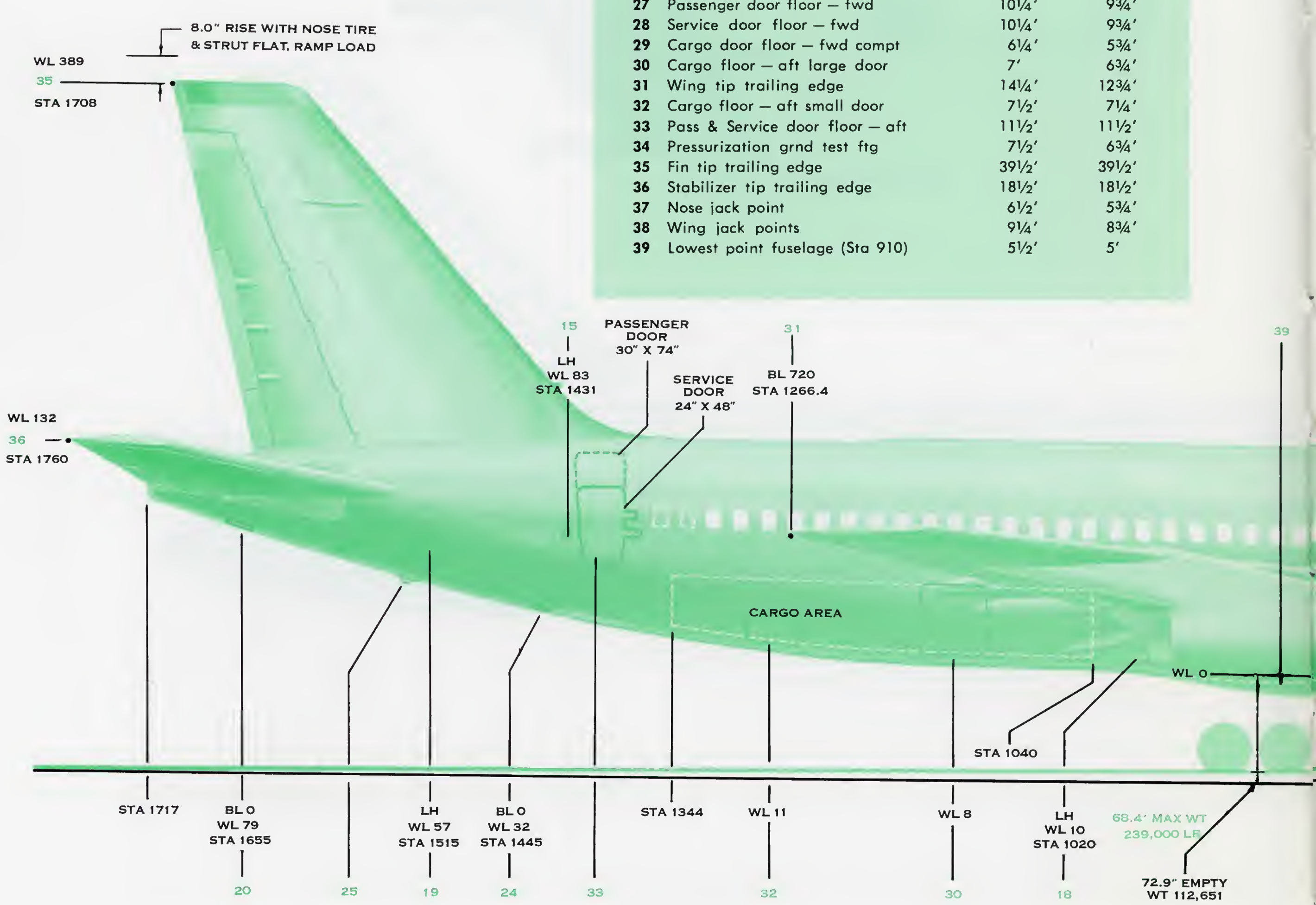
990 ACCESS, SERVICE POINTS AND APPROXIMATE HEIGHTS FROM GROUND

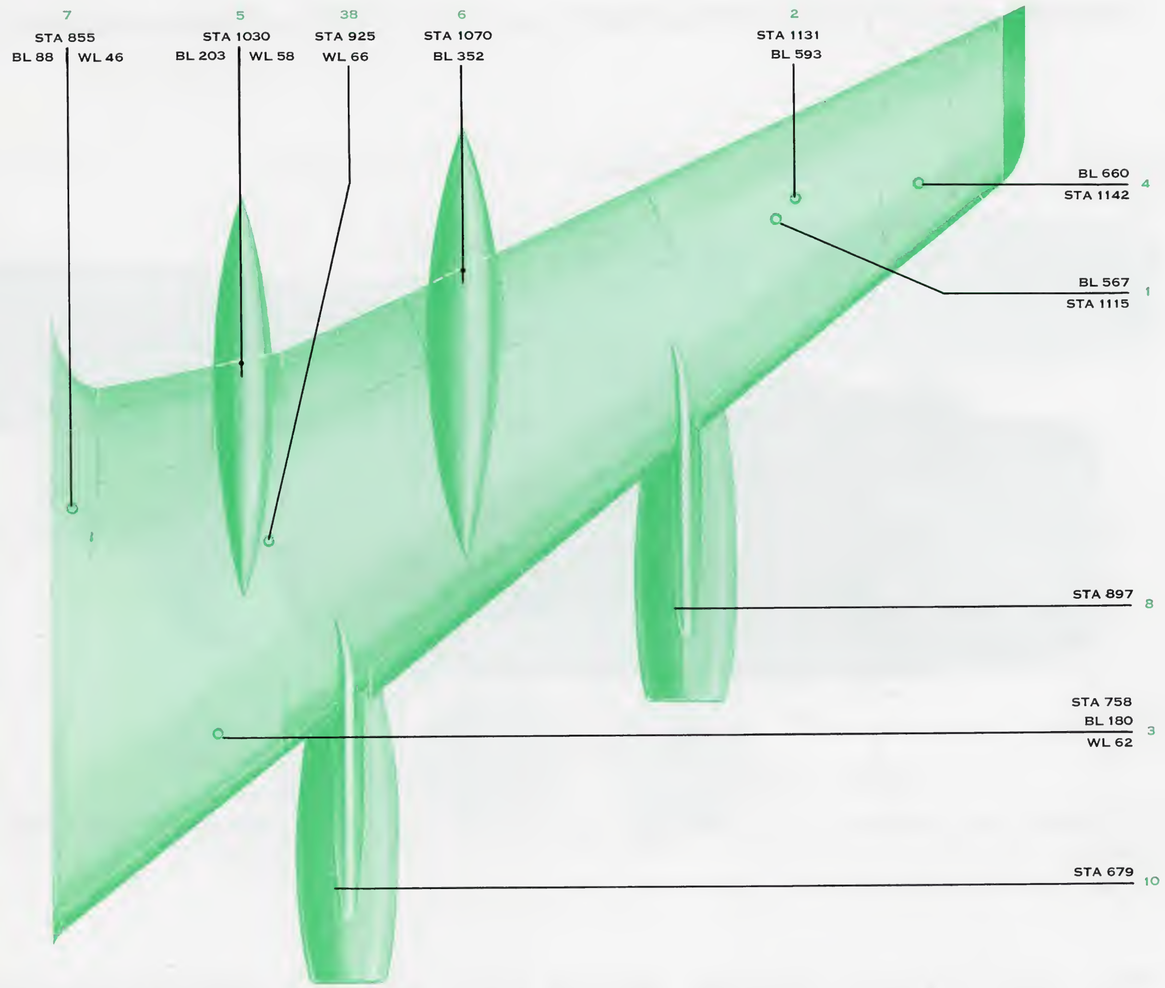
NOTE

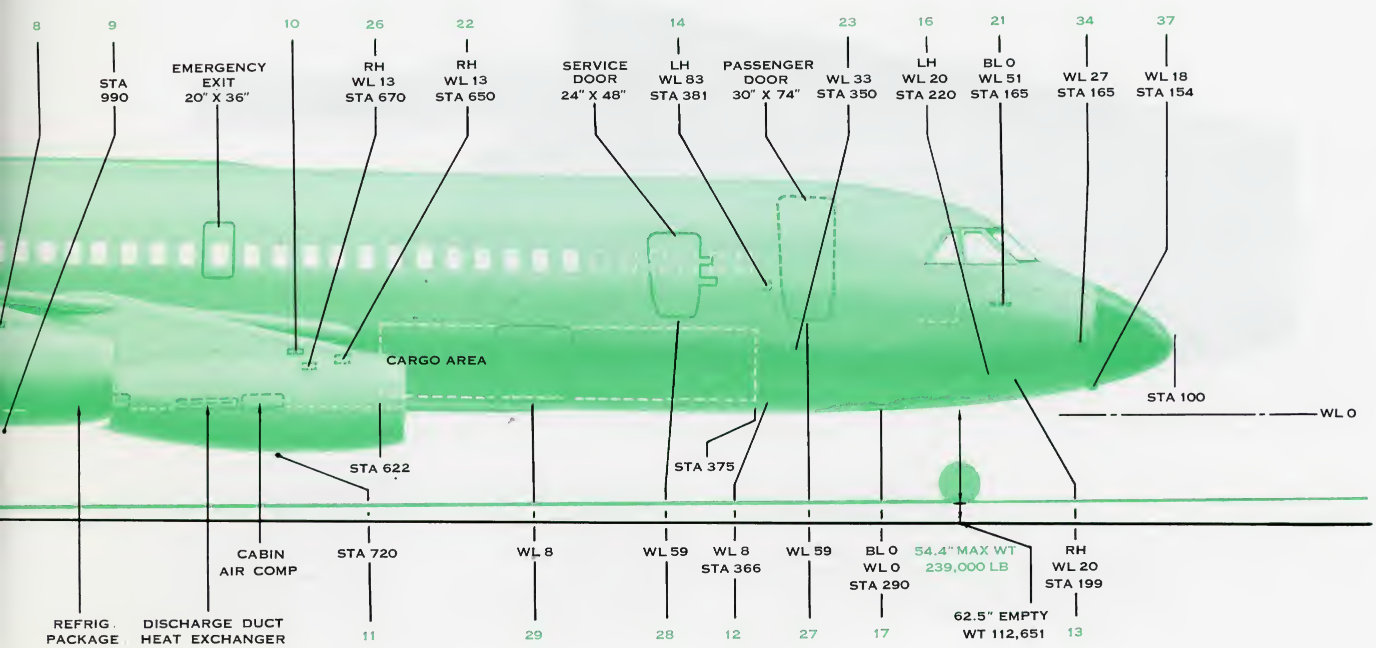
Dimensions and stations on this page are to nearest inch, or nearest ¼ foot, as indicated.

APPROXIMATE HEIGHTS FROM GROUND

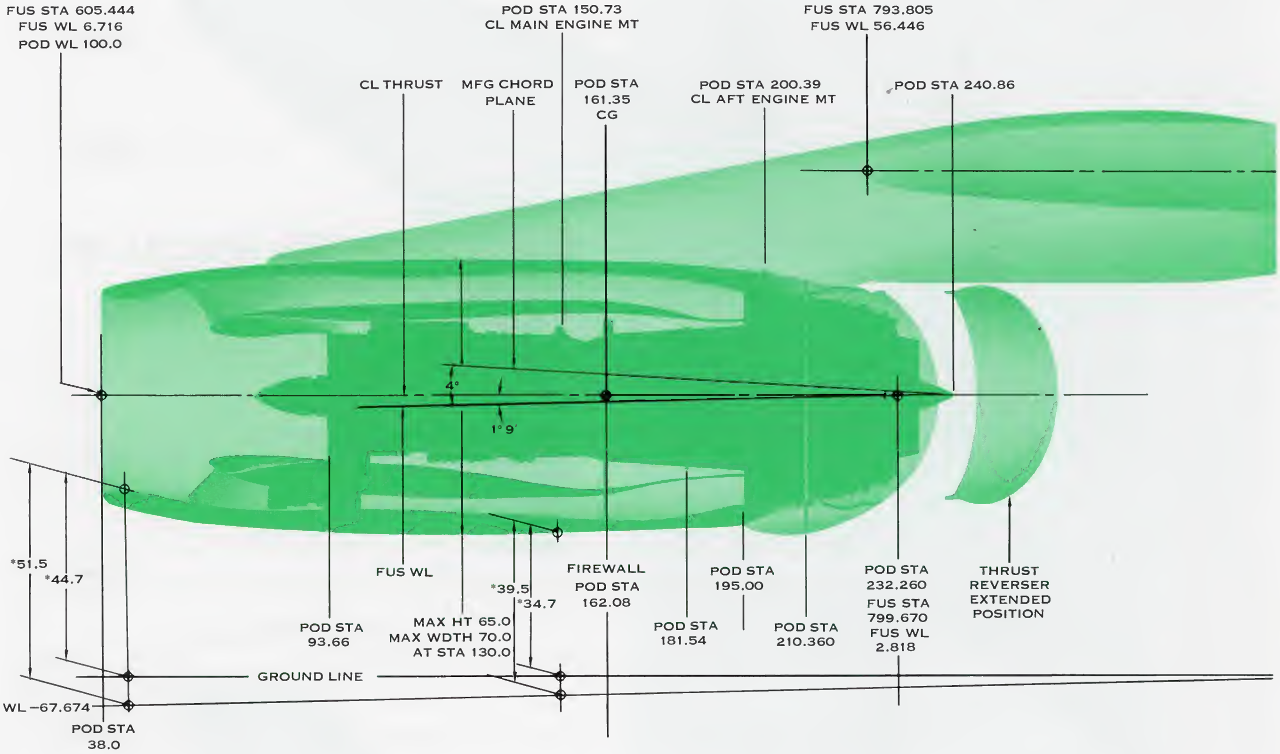
		EMPTY WT 112,651 LBS	MAXIMUM RAMP WT 239,000 LBS
1	Pressure refuel, bottom wing inbd	12′	11¼′
2	Pressure refuel, bottom wing outbd	12′	11¼′
3	Gravity refuel, top wing inbd	11′	10½′
4	Gravity refuel, top wing outbd	13¾′	12¾′
5	Gravity refuel, anti-shock body inbd	11′	10½′
6	Gravity refuel, anti-shock body outbd	12′	11¼′
7	Gravity refuel, center section	10′	9½′
8	Engine & CSD oil, outbd pod	10′	9¼′
9	Lowest point, outbd pod	4¾′	4′
10	Engine & CSD oil, inbd pod	8¾′	8¼′
11	Lowest point, inbd pod	3½′	2¾′
12	Main elec power recept	6′	5½′
13	Nose elec power recept	7′	6¼′
14	Ramp elec recept — fwd	12¼′	11¾′
15	Ramp elec recept — aft	13½′	13½′
16	Elec equipment doors — LH & RH	7′	6½′
17	Electronic equipment door	5¼′	4¾′
18	Hydraulic service points	7′	6¾′
19	Tail cone door — fwd	11½′	11½′
20	Tail cone door — aft	15½′	15½′
21	Nose wheel well top door	9½′	8¾′
22	Water filler inlet	6¾′	6¼′
23	Lavatory service — fwd	8′	7½′
24	Lavatory service — aft	9¼′	9¼′
25	Tail skid	10½′	10½′
26	Low-pressure air inlet	6¾′	6¼′
27	Passenger door floor — fwd	10¼′	9¾′
28	Service door floor — fwd	10¼′	9¾′
29	Cargo door floor — fwd compt	6¼′	5¾′
30	Cargo floor — aft large door	7′	6¾′
31	Wing tip trailing edge	14¼′	12¾′
32	Cargo floor — aft small door	7½′	7¼′
33	Pass & Service door floor — aft	11½′	11½′
34	Pressurization grnd test ftg	7½′	6¾′
35	Fin tip trailing edge	39½′	39½′
36	Stabilizer tip trailing edge	18½′	18½′
37	Nose jack point	6½′	5¾′
38	Wing jack points	9¼′	8¾′
39	Lowest point fuselage (Sta 910)	5½′	5′



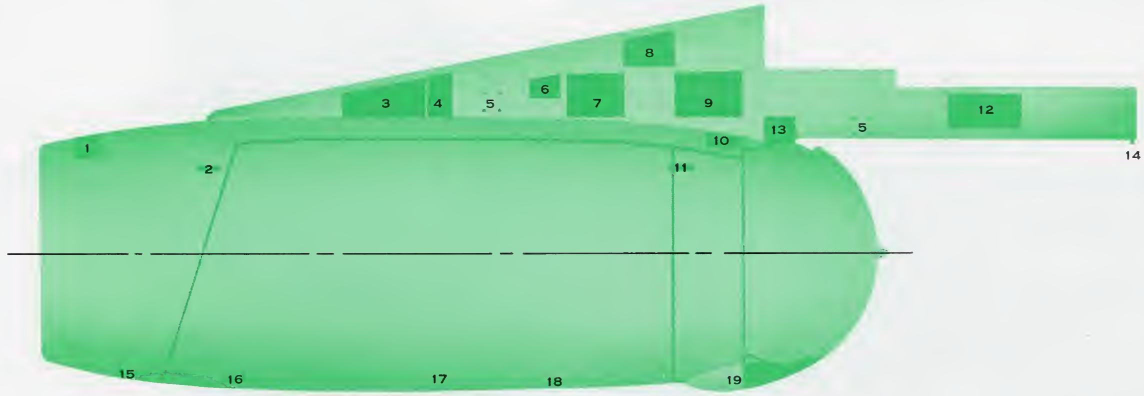

7
STA 855
BL 88
WL 46
5
STA 1030
BL 203
WL 58
38
STA 925
WL 66
6
STA 1070
BL 352
2
STA 1131
BL 593
BL 660
STA 1142
4
BL 567
STA 1115
1
STA 897
8
STA 758
BL 180
WL 62
3
STA 679
10


8
9
STA 990
EMERGENCY EXIT 20" X 36"
10
26
RH WL 13 STA 670
22
RH WL 13 STA 650
SERVICE DOOR 24" X 48"
14
LH WL 83 STA 381
PASSENGER DOOR 30" X 74"
23
WL 33 STA 350
16
LH WL 20 STA 220
21
BL 0 WL 51 STA 165
34
WL 27 STA 165
37
WL 18 STA 154
CARGO AREA
STA 100
WL 0
STA 622
STA 375
REFRIG. PACKAGE
DISCHARGE DUCT HEAT EXCHANGER
CABIN AIR COMP
STA 720
11
WL 8
29
WL 59
28
WL 8 STA 366
12
WL 59
27
BL 0 WL 0 STA 290
17
54.4" MAX WT 239,000 LB
62.5" EMPTY WT 112,651
RH WL 20 STA 199
13

990 POD AND PYLON GEOMETRY AND STATIONS – INBOARD ENGINE

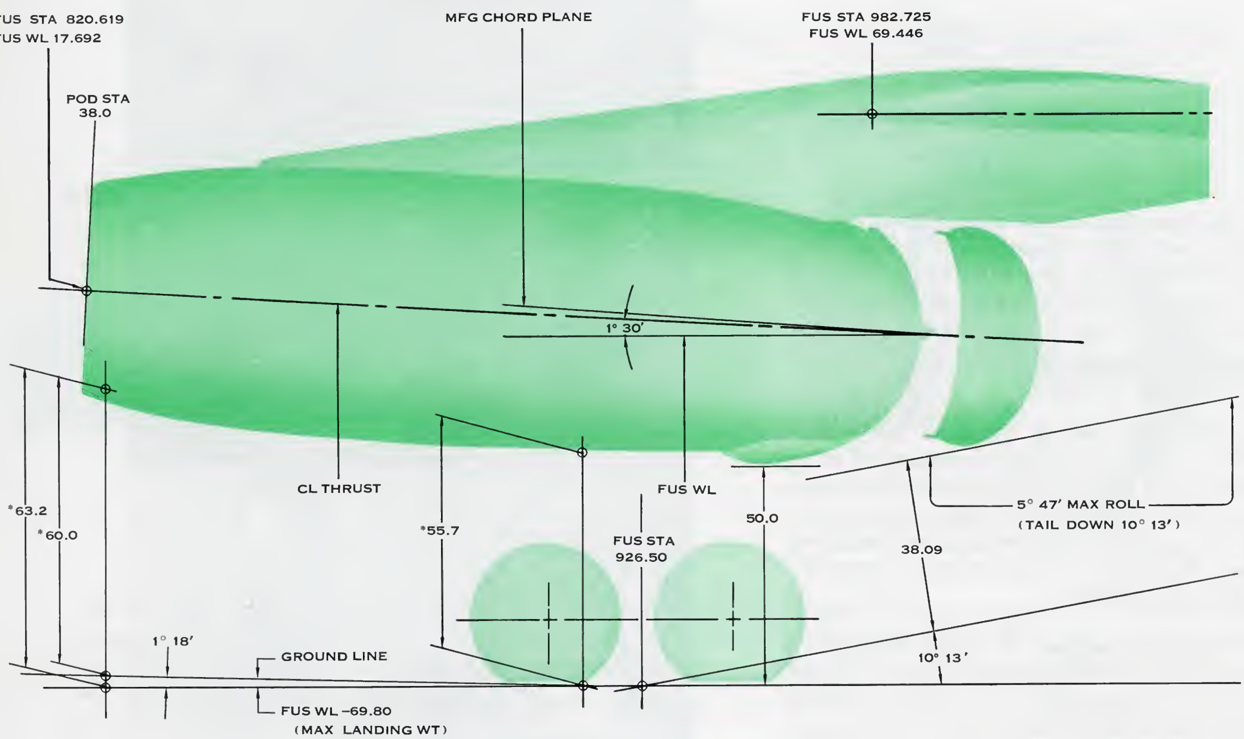


POD AND PYLON ACCESS DOORS AND PANELS – LEFT HAND SIDE



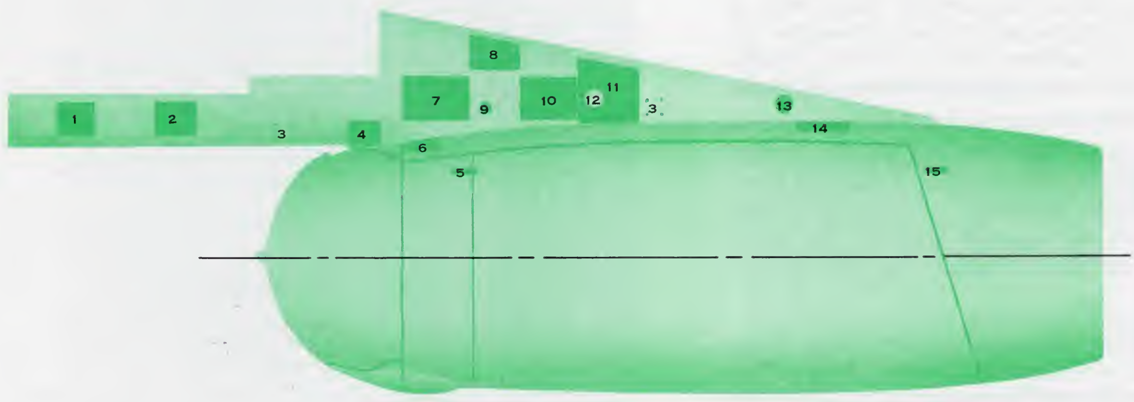
1 Ice detector, temp sensor, & anti-icing duct
2 Shear latch
3 Fluid & elec disconnects
4 Hyd emergency shutoff valve
5 Hoist pad
6 Fluid line access
7 Bleed duct & fluid lines
8 Bleed duct
9 Fluid lines
10 Rear engine mount
11 Shear latch
12 Hyd filters, low pressure warning switch
13 Thrust reverser actuator
14 Pylon drain
15 Interphone jack
16 Fire door
17 Fuel control access
18 Engine & pylon drain
19 Thrust reverser fairing, lower

OUTBOARD ENGINE



RIGHT HAND SIDE

*JIG DIMENSION – NO PYLON OR WING DEFLECTION INCLUDED



1 Elec harness & plumbing supports (inbd pylon only)
2 Side load fitting
3 Hoist pad
4 Thrust reverser fairing, upper
5 Shear latch
6 Rear engine mount
7 Elec harness
8 Bleed duct
9 Frangible blowout disc
10 Bleed duct & elec lines
11 Fire ext bottle & check valves
12 Fire ext quantity gage
13 Engine oil quantity
14 Engine & CSD oil filler
15 Shear latch

NOTE: The two outboard, or two inboard, pod-pylon assemblies are interchangeable. Inboard assemblies are not interchangeable with outboard.

JET ENGINE OIL
MIL-L-7808C

One of the numerous requirements following the advent of the modern gas turbine engine was the need for a special lubricating oil. The new jet engine needed an oil with low viscosity at low temperatures and with a high viscosity index and low volatility. The oil was also required to be non-corrosive and have oxidation stability at high temperatures.

Existing petroleum base oil failed to meet these requirements, so the oil industry concentrated on a synthetic ester-based lubricant which showed the greatest promise. The result was a very thin, colorless oil combining the required characteristics and equaling or exceeding the military requirements covered by Specification MIL-L-7808.

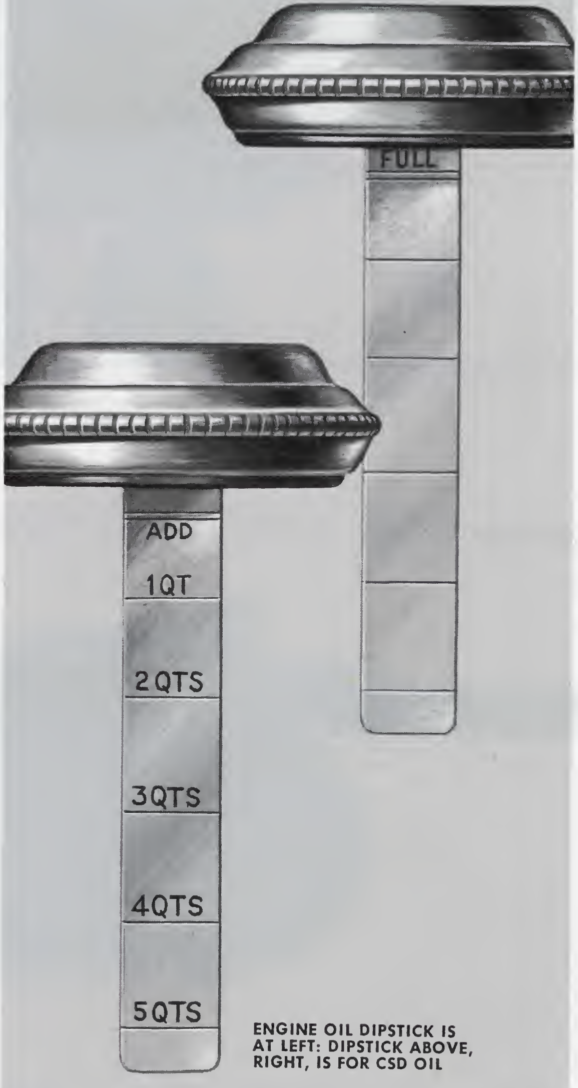
Convair engineers assigned to the lubrication aspects of the Convair 880 found that the thin, colorless oil was nearly indiscernible on an ordinary smooth dip stick. To overcome this difficulty, the engine oil and constant-speed-drive oil dip sticks are vapor blasted during manufacture to a satin or frosted finish. This provides the necessary noticeable contrast between the dry area of the dip stick and the oil-coated portion.

The Convair 880 has four engine oil tanks, one on the right hand side of each engine. Each tank is divided into two compartments: one for engine oil which holds 4.15 gallons, and the other for the constant-speed-drive and thrust reverser oil which holds 1.72 gallons.

Near the top of the tanks, through an access door in the upper nacelle quadrant, there are screened gravity fill ports with the dip sticks attached to the filler caps. Servicing for both the engine oil and CSD and thrust reverser oil is performed through the same nacelle door.

The oil dip sticks are approximately 3 inches long and are marked off in quart increments. The stick length is governed by the filler port screen depth which extends a little more than 3 inches below the port opening. The dip sticks are primarily used to facilitate oil tank servicing. The engine oil dip stick indicates oil level below full, down to 5 quarts and the CSD-thrust reverser oil dip stick indicates 1 quart plus.

Primary quantity gaging for the engine oil tank is accomplished by a capacitance probe in the tank with a readout in the flight compartment.



ENGINE OIL DIPSTICK IS AT LEFT: DIPSTICK ABOVE, RIGHT, IS FOR CSD OIL

Servicing the Convair Jet Airliners

to meet demands of competitive scheduling – jet transports must be designed to permit efficient servicing operations

By the time the Convair 880 and 990 aircraft go into regular service, many of the world's major airports will be equipped for handling large jet airliners and will have had experience in their servicing. To such airports, the "880" and "990" will present few new requirements.

The Convair transports will, however, be serving airports where the larger jets now flying do not often land. Type of fuel, hydraulic fluid, and lubricating oil will differ from that required for most propeller aircraft. Jet engines, unless the airplane is one of the few with a self-contained starting system, all require a source of pneumatic power for the turbine starters. Ground air conditioning requirements for transports the size of the Convair jet airliners are greater. External electric power is a-c, and loads are larger than in piston-engine transports.

Another aspect of jet airplane servicing is the urgency to save time. Besides the matter of passenger convenience in making stopovers brief as possible, an idle jet transport is costly. Turnaround and maintenance time must be kept to a minimum.

Expediting servicing and maintenance has been a prime objective through all design stages of the Convair 880 and 990. Engineering groups were charged with seeing that the airplane's major systems are quickly accessible, easily serviced with minimum special ground support equipment, with components quickly replaceable when necessary.

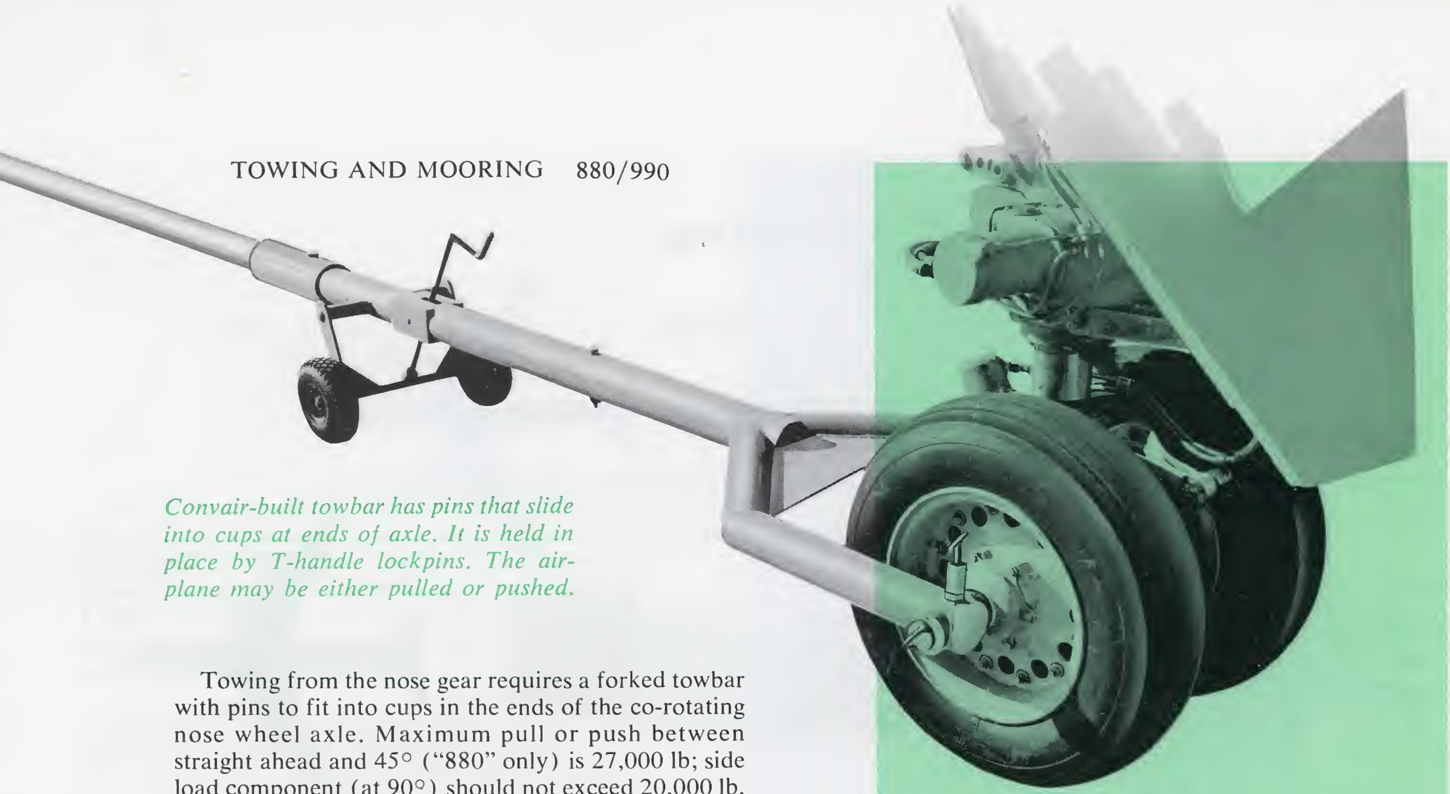
Ground service points are located so that normal servicing operations can be conducted simultaneously, without inconvenience to passengers, from the instant the airplane rolls up to the ramp until it is ready to leave. The forward lavatory service panel is the only turnaround service point on the left-hand side of the fuselage; buffet, electrical, air and water carts will be on the right-hand side. All fuselage service panels except the lavatory can be reached by a man standing on the ground.

Air conditioning, pressurization, and hydraulic systems will normally require only inspection for leakage and fluid levels. Emergency equipment—passenger oxygen cylinders and fire extinguishers—need replacement only after use or after prescribed time lapses. Engine pod doors will usually not be opened on a turnaround; lubricating oil tanks can be serviced through an access door in the upper pod structure. The only other engine point that might require servicing during stopover is a fuel drain tank that should be drained after two unsuccessful engine start attempts.

Refueling is most rapid and most convenient through pressure fittings, two on the under surface of each wing. Gravity fill connections are also provided on the upper surfaces. There are no walkways on the wing; design is such that the wing box section can be walked on if proper precautions are taken against marring the surface.

Water and lavatory fittings are standard. Cleaning equipment, passenger ramps, and cargo handling and galley service equipment will be like that presently in use for passenger transports. The differences that may arise will be only those associated with the fact that "880"- "990"aircraft are larger, and stand higher, than most propeller-driven transports.

The following pages contain illustrations and more specific lists of requirements for routine servicing of the "880" and "990".

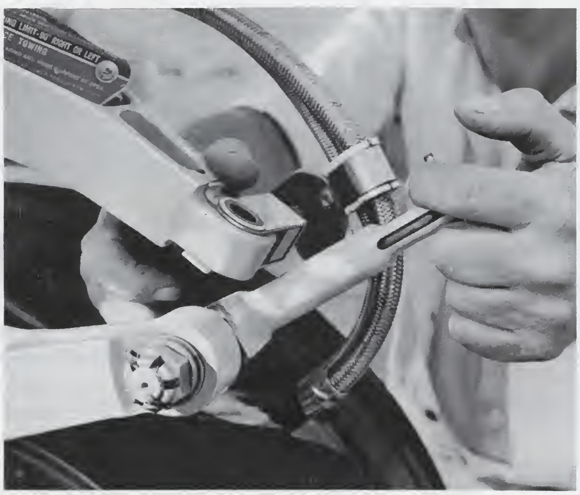


Convair-built towbar has pins that slide into cups at ends of axle. It is held in place by T-handle lockpins. The airplane may be either pulled or pushed.

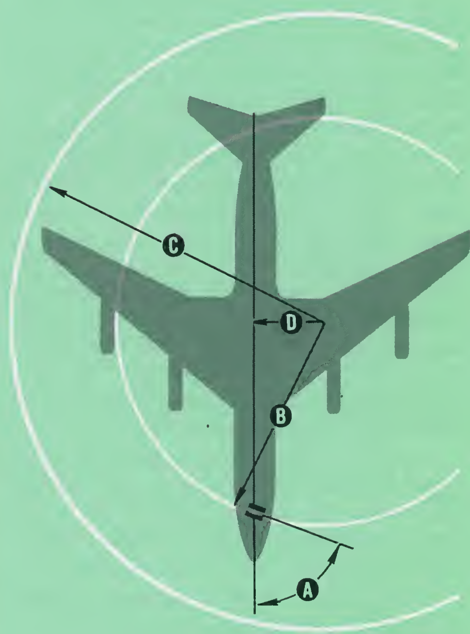
Towing from the nose gear requires a forked towbar with pins to fit into cups in the ends of the co-rotating nose wheel axle. Maximum pull or push between straight ahead and 45° ("880" only) is 27,000 lb; side load component (at 90°) should not exceed 20,000 lb. Nose wheel steering may be disconnected by pulling a pin at the apex of the torque links. A 360° turn is possible only if brake lines are also disconnected.

The airplane may be towed by cable from lugs on forward and aft ends of the main gear trucks. Pull limit ("880") is 20,100 lb on each gear within 30° of the truck beam axis. This method, requiring two tractor units in close coordination, can be utilized in mud, snow, or over rough terrain.

The airplane can be moored at the nose gear and by use of the towing lugs on the main trucks. Experience has been that aircraft heavy as the Convair jet airliners require mooring only in extraordinary storm conditions. Control surfaces are always protected by the gust dampers.



Quick disconnect pin releases nose gear torque link and hose support, allowing sufficient turn angle for normal towing operations at airport.



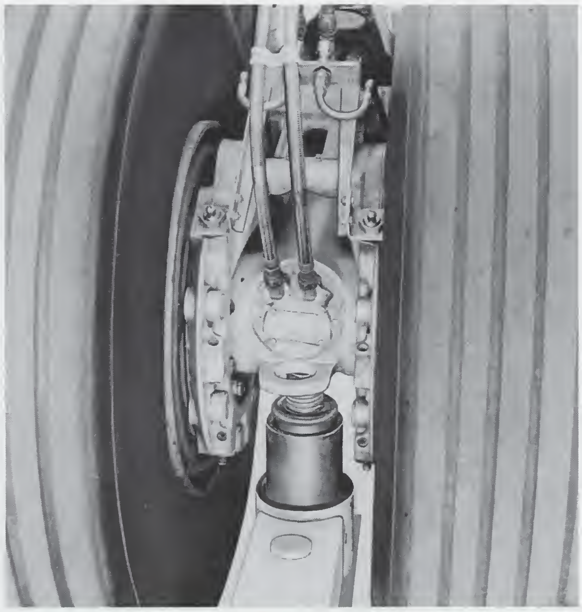
TURNING RADIUS

		880	990
A	Maximum turn angle	70°	63°
B	Minimum turn radius	56′ 9″	64′ 5″
C	Wingtip clearance radius	84′	93′ 8″
D	Pivot point BL at MLG CL	19′ 5″	29′ 3″

JACKING 880

Landing gear jack pads are located under nose and main gear struts, and under main gear axles. A jack for the nose gear or for one main gear axle should have a 25-ton capacity, 5-inch maximum width, 7-inch minimum height, 3-inch screw extension, and 12-inch lift. Jacks to raise a main truck at the center jack pad should have a 50-ton capacity, 7-inch maximum width, 8-inch minimum height, 3½-inch screw extension, and 9-inch lift. For use with electronic weighing cells, minimum heights should be an inch less.

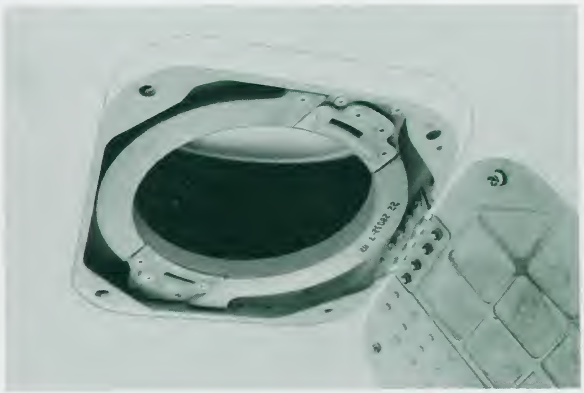
Wing jack joints will be at 91-inch minimum height with all four tires on one truck deflated; the fuselage nose jack point, with both nose tires deflated, will be at 65-inch minimum height. Approximately 26 inches extension of wing jacks would fully extend the strut and lift the tires clear of the ground, and approximately 22 inches extension at the nose jack. The struts may, however, be compressed by external means before jacking. Maximum load at normal CG limits on wing jacks is 64,000 lb, and at the nose jack 12,000 lb.



Jack of 25-ton capacity may be used on nose gear or on main truck axle, as shown. Eye may be used for towing or mooring, if necessary.

GROUND AIR CONDITIONING 880/990

With engines shut down, conditioned air can be supplied directly to the airplane without using the airplane Freon systems. Requirements are a unit supplying a maximum airflow of 160 lb/min at a maximum pressure of 1 inch Hg, maximum temperature 130° F, minimum temperature 32° F, designed to operate at ambient temperatures from -40° F to 99° F. Nominal cooling rate should be 25 tons, heating rate 400,000 BTU/hr.



Conditioned air may be pumped directly into "880" air conditioning system through fitting on right-hand side forward of wing leading edge.

ELECTRIC GROUND POWER 880/990

The airplane a-c current requirement is 120/200-volt, 400-cycle, 3-phase, 4-wire, Y-connected, 0.8 lagging power factor. For aircraft with electrically-operated air conditioning systems, the unit should have a thermal rating of 125 kva; for other aircraft, 65 kva.

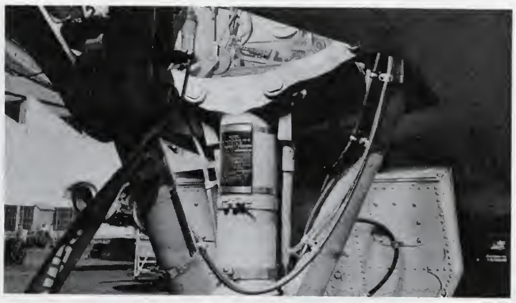
The 125-kva unit should be capable of providing power in the following steps: Upon a preload of 15 kva at 0.8 power factor applied initially will be superimposed a 420-ampere, 0.2-power-factor motor inrush for 1.75 seconds. After a minimum 1-second delay, with unit under maximum preload of 55 kva at 0.8 power factor, a second motor inrush of 270 amperes at 0.2 power factor will be applied for 3 seconds.

The 65-kva unit should be capable of providing power as follows: Upon a preload of 15 kva at 0.8 power factor applied initially will be superimposed a 200-ampere, 0.2-power-factor motor inrush for 1.75 seconds.

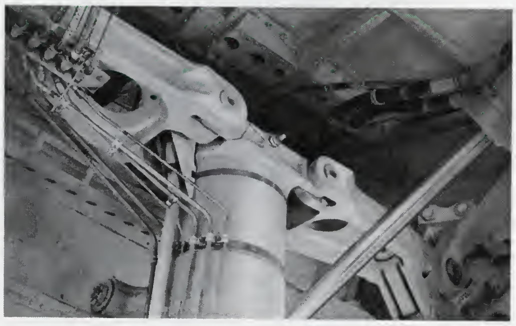
In both units, upon application of the loads described, output voltage should recover to and remain with ±2% of regulated voltage in a maximum of .15 seconds. Maximum output voltage dip should not exceed 41% of the regulated value. Units should be capable of delivering 300% current into a sustained 3-phase short circuit for 6 seconds without overheating or mechanical damage.

External power receptacles may be single, or dual units. The "990" Model 30-5 has extra receptacle near nose gear for use while towing.

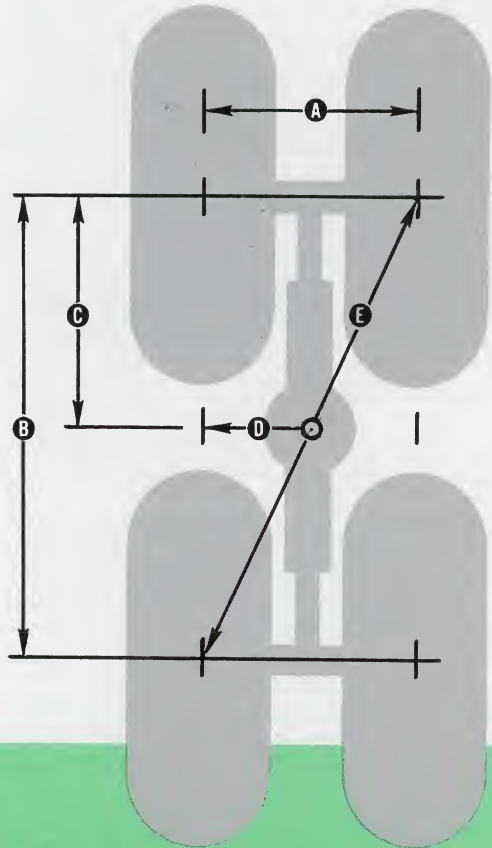
Landing Gear



Instructions for servicing nose gear strut appear on placard. Air fitting and gage for brake flask are inside door frame, upper right (not visible).



Air fitting for pressurizing main gear strut is shown at top. Placard (on other side, not shown) gives strut extension with airplane fully loaded.



MAIN GEAR TRUCK DIMENSIONS

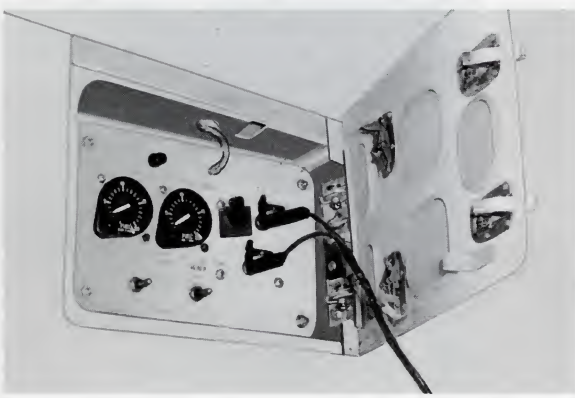
MODEL	DIMENSIONS A	B	C	D	E
880 all versions	21.5	45.0	22.5	10.75	49.87
990 all versions	24.0	46.5	23.0	12.0	52.32

High-Pressure Pneumatic Table

UNIT	LOCATION OF FITTING	UNIT CAPACITY 880	UNIT CAPACITY 990	PRESSURE 880	PRESSURE 990
Emergency air brake bottle	Nose wheel well	400 cu in		220 psi	
Hydraulic system accumulators (2)	Hydraulic Compartment	100 cu in each		900 psi	
MLG accumulators (2)	Hydraulic Compartment	400 cu in each		900 psi	
Anti-skid brake modulator	Hydraulic Compartment	50 cu in		250 psi	
NLG strut, static position	Top of strut	71.5 cu in		1180 psi	1070 psi
MLG struts, static position	Top of strut	234 cu in each	—	1712 psi	1994 psi
MLG truck positioners	Aft end of truck	17.5 cu in each		995 psi (with weight off MLG trucks)	

Analysis of Wheel Loading

	880	600
LOADING CONFIGURATION:		
Maximum ramp weight	185,000	239,000
Maximum takeoff weight	184,500	238,200
Maximum landing weight	132,800	180,000
TIRE SIZE AND PLY RATING:		
Nose	29 x 7.7, 12 PR	29 x 7.7, 16 PR
Main	39 x 13, 20 PR	41 x 15-18, 20 PR
TIRE CONTACT AREA:		
Nose	68 sq in	68 sq in
Main	170 sq in	205 sq in
RATED INFLATION PRESSURE:		
Nose	160 psi	220 psi
Main	150 psi	155 psi
RATED STATIC LOAD PER TIRE:		
Nose	9,800 lb	13,800 lb
Main	22,300 lb	28,600 lb
AIRPLANE STATIC LOAD PER TIRE:		
Most forward CG:		
Nose	7,810 lb	10,450 lb
Main forward truck	20,611 lb	27,262 lb
Main aft truck	21,733 lb	27,262 lb
Most aft CG:		
Nose	5,860 lb	6,560 lb
Main forward truck	21,099 lb	28,235 lb
Main aft truck	22,221 lb	28,235 lb
AIRPLANE TIRE PRESSURE:		
Most forward CG:		
Nose	128 psi	166 psi
Main forward truck	139 psi	148 psi
Main aft truck	146 psi	148 psi
Most aft CG:		
Nose	95 psi	105 psi
Main forward truck	142 psi	153 psi
Main aft truck	149 psi	153 psi
TIRE CONTACT PRESSURE:		
Most forward CG:		
Nose	114 psi	153 psi
Main forward truck	121 psi	133 psi
Main aft truck	128 psi	133 psi
Most aft CG:		
Nose	86 psi	96 psi
Main forward truck	124 psi	137 psi
Main aft truck	130 psi	137 psi



REFUELING
880/990

Total capacity of the 880M wing box section is 10,776 gallons; total capacity on the "990" is 10,904 gallons. Center section fuel cells in the "880M" hold an additional 1,875 gallons, while on the "990" they hold an additional 3,148 gallons. On some "990's" with anti-shock bodies, an additional 1,136 gallons are carried; on others the capacity is 1,636 gallons.

Refuel panel on "880" is on outboard side of inboard pylons. On "990," panel is on underwing surface in trailing edge outboard of engines.

The four underwing pressure fittings have a flow capacity of 300 gpm each at 50 psig fuel pressure. Overwing gravity fuel fittings have flush type caps with 3-inch filler necks.

To hold refueling time to a minimum, equipment should have sufficient capacity to service both tanks on each wing simultaneously, pumping 600 gpm at 50 psig.

Inboard and outboard pressure refuel fittings are side by side, outboard of inboard engine on "880," outboard of outboard engine on "990."

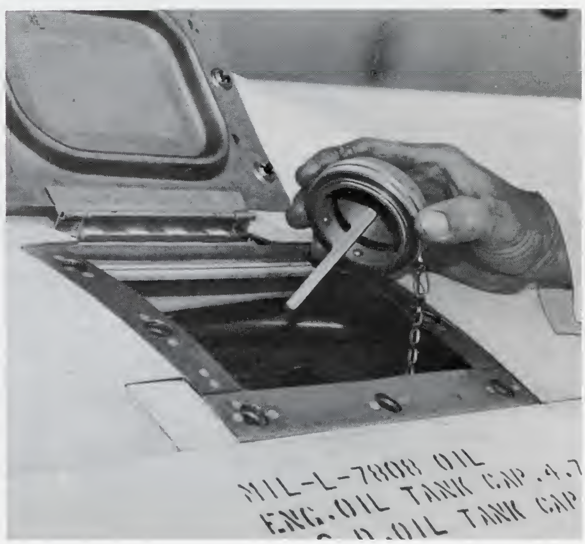
PRESSURIZATION AND AIR CONDITIONING 880/990

Liquid level sight gages, visible through a porthole in the air conditioning access doors on the bottom of the fuselage, show Freon level. Gages should be read periodically during operation with condenser as cold as possible. If the level is below 4, the package should be drained, checked for leakage, purged, and refilled with Freon to which approximately 5% by weight of lubricant has been added.

Oil level in the turbocompressor should be checked periodically. Level should be above sight line in the gage on the compressor and turbine drive oil sump. If level is visible, oil should be added to the level of the filler plug.

Lubricant specifications are in the fluid table on Page 263.

Freon level gages are on bottom of fuselage. Replenishing freon is lengthy procedure, requiring draining and complete purging of system.

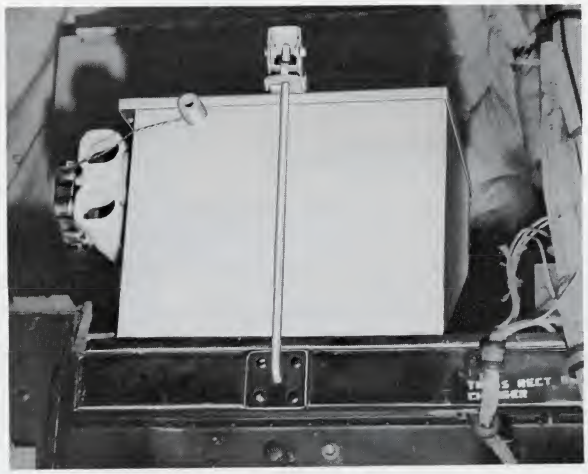


Checking engine oil levels, right, requires a ladder. Engine and CSD tanks have separate dipsticks as well as ports for gravity refilling.

BATTERY
880/990

Since the 27.5-volt storage battery in the "880" and "990" is only standby for use in exceptional emergencies, it requires a minimum of servicing. Rate of charge and discharge, amperage, and voltage can be monitored from the flight engineer's panel. The battery should be inspected every 250 hours of aircraft operation and the electrolyte level checked every 500 hours.

The electrolyte is caustic rather than acid. Hydrometers or syringes used with acid batteries should not be used in servicing nickel-cadmium batteries.

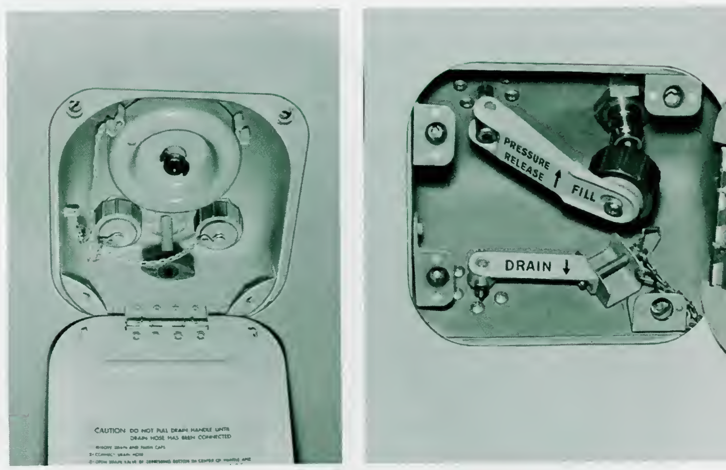


Battery is on aft face of bulkhead aft of radome. View is from electrical compartment. Normal access is through the top of nose wheel well.

WATER SYSTEMS AND LAVATORIES
880/990

Water capacity of the Convair "880" and "600" is 50 gallons. The service cart should have a pump with a minimum capacity of 10 gpm. Since potable water is required, the cart tank and lines should be corrosion-resistant and suitable for use with water containing 20 parts per million of chlorine.

The lavatory service cart should have a waste tank of 70 gallons minimum capacity and a 20-gallon-minimum supply tank for flushing. The cart should have a platform for standing on; the forward service panel is approximately 7½ feet from ground level. In the "600", the aft panel is even higher, approximately 9 feet 3 inches.



On left is aft lavatory drain; forward drain is on left side of "880," on right side of "990." On right are the water service drain and fill fittings.

OXYGEN SYSTEM
880/990

Gaseous oxygen is stored in cylinders in the flight compartment, and in portable units in flight compartment and cabin. All cylinders have pressure gages and should be checked periodically and replaced when necessary.

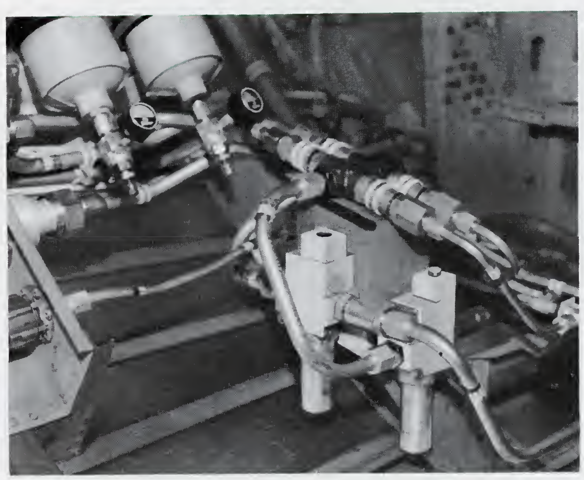
Since one crew member must be on oxygen during high-altitude flight, one of the main supply cylinders will require frequent replacement. The cylinders are lightweight, approximately 9 inches in diameter by 30 inches long, except as noted below. They hold 107 cu ft at 1800 psi. Cylinder and valve assembly is Zep Aero P/N ZC-268-111. Weight fully charged is 44.8 lb.

HYDRAULIC SYSTEMS
880/990

Servicing will not normally be required for hydraulic systems of the "880" and "990" aircraft on stopovers or turnaround. Fluid quantities can be read at the copilot's panel.

If necessary, major system components are accessible through a door on the left-hand side of the fuselage, aft of the wing. System and MLG accumulators are just inside the doors. The emergency air brake flask, in the electrical compartment over the nose wheel well, has its pressure gage and fitting on the nose gear door frame.

On each "880" pylon are two small transparent windows for checking hydraulic filters. Red pop-up buttons



View in hydraulic compartment shows main accumulator gages and filters. Button on right has popped out, showing filter that needs servicing.

will be forced out by excessive pressure drop across the filters, to warn when they need servicing. Two such filters, for ground cart or auxiliary pumps, are in the "880" hydraulic compartment.

LOW-PRESSURE AIR
880/990

A ground source of compressed air is necessary to start the engines. It may be used to operate the air conditioning system on aircraft using bleed air as an air conditioning power source.

Requirement is for a flow of 100 lb/min at a pressure of 48 psia under conditions of sea-level ambient pressure, 100° F ambient temperature, and airflow temperature of 435°.

For engine start, some aircraft have connections for using a ground cart in-line combustor on one or both of the right-hand engines. At the higher temperature of this flow, the lb/min requirement is correspondingly lessened.

Below, pressure air line is being connected for engine start. On some "880" aircraft, the air connection is forward at the nose wheel well.

Ground Service Connections 880M/990

	FITTING	VENDOR P/N OR MIL SPEC
1	Conditioned air (880 only)	MS 33562 ABC Std
2	Gas turbine compressor	Bobrick 914 (conforming to AF Dwg 54 B 9301)
3	Engine start in-line combustor (optional)	Wiggins GSN-151-C-35D
4	Lavatory service:	
	Drain (880)	Roylyn 2651-127D
	Drain (990)	Roylyn 2651-127
	Flush (880/990)	Roylyn 1002-16
5	Water system	Roylyn 1002-12C
6	Pressure refuel	Parker 1327-575699 (conforming to MIL-A-7898, Type A5)
7	Hydraulic pressure fill	Aeroquip 305503-S11-6D
8	Hydraulic pressure line	Aeroquip 305503-S11-12D
9	Hydraulic return line	Aeroquip 307012-S11-1D
10	Hydraulic accumulators and brake air flask	MS 28889-1
11	External power receptacle	AN3114-1B
12	Soldering iron receptacle	Hubbell 7332
13	Passenger ramp receptacle	Hubbell 10108
	Interphone: Jacks	Mallory SCA-28
	Boxes	Mallory SC-1A, Trimm 95-25

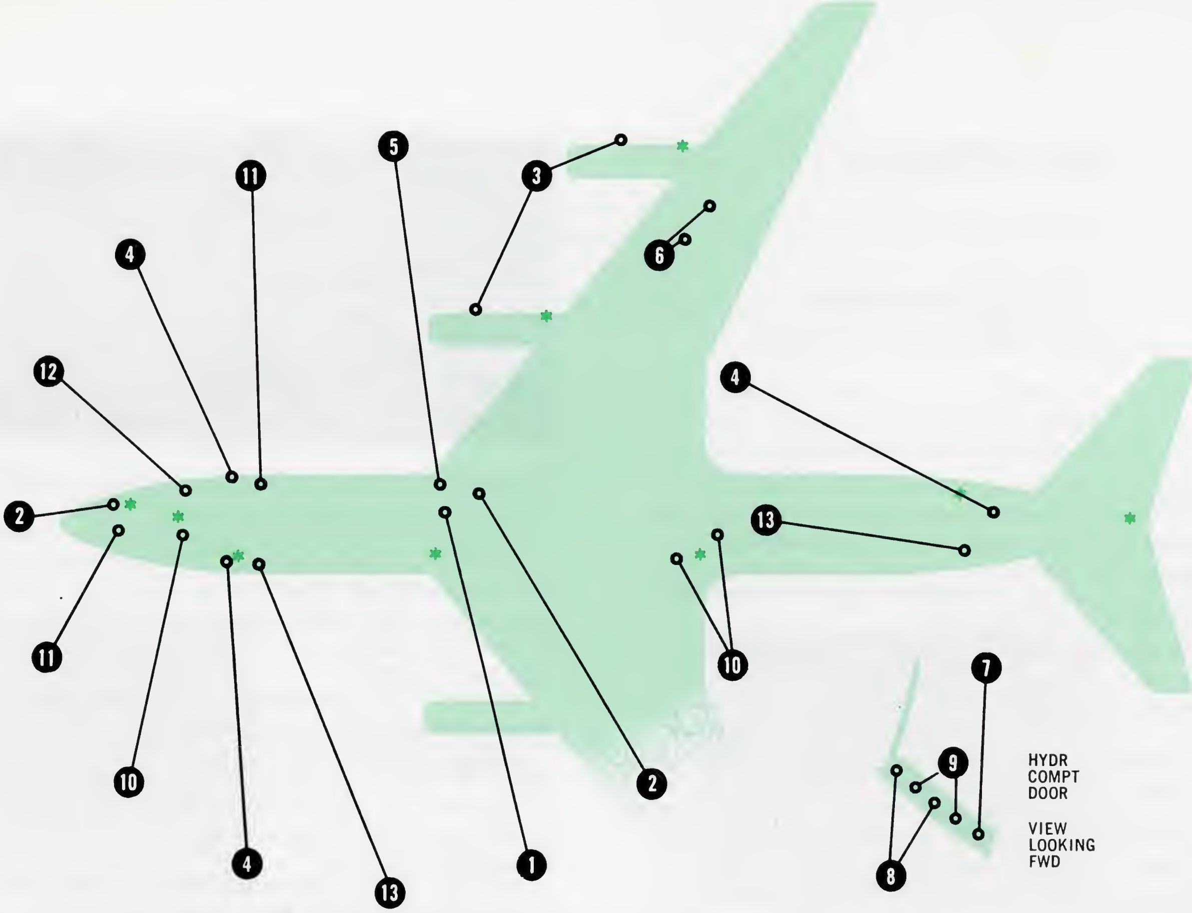


Table of Fluids

FLUID	SPECIFICATION	COLOR	UNIT CAPACITY 880	UNIT CAPACITY 990	QUANTITY PER AIRPLANE FOR COMPLETE SERVICING 880	QUANTITY PER AIRPLANE FOR COMPLETE SERVICING 990
Fuel	JP-4 or kerosene		See text		10,770 gal	15,108 gal
Lubricating oil, engine	MIL-L-7808C		Engine, 4.15 gal CSD, 1.72 gal		23.48 gal	
Lubricating oil, turbo compressor	MIL-L-6085 (Esso Univis B-38, Aero Shell Fluid 12, or equivalent)				Approx 1 qt	
Lubricating oil, Freon additive	Fed. Spec. VV-L-820 (Texaco Capello AA or equivalent)		15 oz per unit		Approx 1 qt	
Freon 114	Dichlorofluoroethane		Approx 16 lb each		36 lb	
Hydraulic Systems	Skydrol 500A	Purple	Approx 11½ gal. in No. 1 and No. 2 reservoirs		Approx 45 gal in No. 1 and No. 2 systems	Approx 50 gal in No. 1 and No. 2 systems
NLG strut	MIL-H-5606A (MIL-H-6083 fluid, which is MIL-H-5606A with rust inhibitor additive, may be used in lieu of MIL-H-5606A)	Red	Approx 1 gal	Approx 1 gal	Approx 5 gal	Approx 6 gal
MLG strut			Approx 2 gal each	Approx 2½ gal each		
MLG truck positioner			Approx ¼ pt each		Approx ½ pt	
NLG liquid spring			Approx 1 pt	None	Approx 1 pt	None
Water	Potable		50 gal or 75 gal	50 gal	50 gal	50 gal
Engine fire extinguisher	Bromotrifluoromethane		6½ lb each		26 lb	

SAFETY WITH JET ENGINE FUELS

The most common types of jet fuels used in today's jet airliners are the kerosene-type fuels. Although the Convair 880/990 is capable of burning different fuels, ranging from high-grade aviation gasoline to straight kerosene, kerosene will probably remain the standard operating fuel for some time.

All personnel who are engaged in handling or working with kerosene jet fuel should be fully acquainted with its characteristics and make a habit of practicing a few simple safety rules. Kerosene is potentially dangerous and should be respected as such. Safety first can rule out injury and damage later on.

Kerosene fuel resembles gasoline and is either straw-colored or colorless. It is lighter in weight than is water; its vapors are heavier than air, and it is moderately volatile. A 1-to-6 percent kerosene vapor mixed with air forms an explosive mixture.

Mechanical shock does not ordinarily affect kerosene fuel. When mixed with liquid oxygen or other strong oxidizers, however, it forms a dangerously explosive mixture which can be set off by shock. A mixture of this type will also explode violently if exposed to a spark or open flame.

If mild concentrations of kerosene vapor are inhaled for more than 3 or 4 minutes, headache, dizziness, and nausea can result. Stronger fumes can anaesthetize, and prolonged inhalation can cause death. When taken internally, kerosene will have the same effects as inhalation with the added discomforts of burning and irritation of the mucous membranes.

It is not necessary to wear special clothing or equipment when handling kerosene fuel in well-ventilated areas. If clothes become soaked with kerosene, they should be removed immediately and any affected skin area should be washed with generous amounts of soap and water. The fuel will not affect the skin adversely if it is washed off quickly. If kerosene fuel should contact the eyes, they should be washed immediately with clean olive oil, castor oil, or water if oil is not available. In any event, prompt medical attention should be obtained.

Smoking should not be permitted in an area where kerosene fuel is being poured or transferred. When pouring the fuel from one container to another, the lip of one container should rest on the other, first making sure that the lower container is resting on a grounded surface. Keeping the two containers in contact during the entire transfer operation prevents the buildup of static charges of electricity during the pouring. As with other fuel, fire-fighting personnel and equipment should be on a standby basis and readily available whenever kerosene fuel is being transferred.

Kerosene fuel storage containers, pipe lines, pumps, and related equipment must all be properly grounded and have adequate bonds across joints and flanged connections. Only nonsparking tools should be used in the fuel storage area, or when working around associated systems.

All cables, clips, braid, and other connections, used for grounding static electricity on fuel containers and handling equipment should be frequently inspected and kept in good condition. The maximum allowable resistance is 10 ohms between fuel tanks, tanks to ground, and nozzle to tank, when connected for filling or transfer operations.

Kerosene fuel storage containers, including cans, drums, or storage tanks, must all be kept tightly sealed to prevent excessive evaporation. At least 10 percent air space should be maintained in all storage vessels to allow for expansion.

The area where kerosene fuel is stored must be kept free of all combustible material to prevent fire spreading, should a fire occur. If fuel is spilled, the area should be flushed with quantities of water to dilute the concentration. If possible, spilled fuel should be collected in suitable containers and removed to a safe area where they can be burned or disposed of by other means.

Flushing and diluting liquid kerosene does not remove vapor concentrations. Since concentrations of kerosene vapor are more hazardous than is the fuel in liquid form, extreme caution must be exercised to ascertain that vapor concentrations have been dissipated.

Fuel clean-up rags should be quickly disposed of, as should the smallest quantities of kerosene fuel. If the fuel is allowed to soak into the ground, it remains for years as a potential danger where oxidizers are likely to be spilled.

Remember these safety rules when working with kerosene:

Ground all equipment properly.

Stop pumps when trouble occurs.

Keep containers in contact with one another when transferring fuel.

Keep storage area free of combustibles.

Wear a breathing mask when entering tanks.

Use only those lubricants, packing materials, and gaskets recommended by proper authority.

DO NOT SMOKE!

Emergency Equipment and Procedures

Convair 880M

Efficient handling of an airplane in an emergency situation requires some acquaintance with its special equipment, escape provisions, and its danger areas when fire threatens.

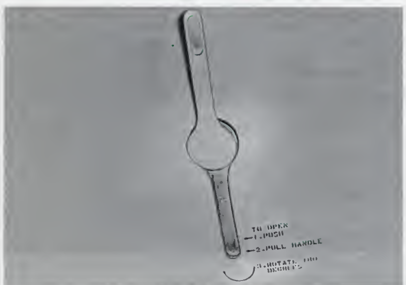
Herein is presented a summary of some Convair 880 design features and equipment installations that will be of interest to those concerned with possible airport emergencies.

It is not the intent here to go into specific flight or ground crew operational procedures. These will be worked out in accordance with governmental regulations, operating line procedures, and airport firefighting and rescue facilities.

Much of the cabin and flight deck equipment is specified by the individual operator. The installations pictured herein must therefore be accepted only as typical of the Convair 880.

EMERGENCY EXITS

TO OPEN CABIN DOORS, PUSH RELEASE CATCH, PULL HANDLE, ROTATE IT 180°.



TO OPEN COCKPIT WINDOW, PUSH CATCH AND TURN HANDLE TO ROLL WINDOW AFT.

EMERGENCY HATCH INTERIOR RELEASE IS AT TOP, WITH HANDHOLD AT BOTTOM.

PULL COVER DOWN, PULL T-HANDLE, AND LIFT OUT THE HATCH AND LAY IT ASIDE.

TO OPEN HATCH FROM OUTSIDE, PUSH ON PLATE TO RELEASE; PUSH HATCH IN.

EMERGENCY DEPLANING

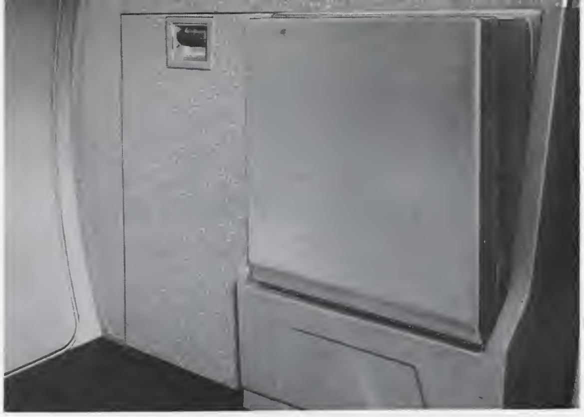
For rapid evacuation of passengers in an emergency, inflatable escape chutes are provided at forward and rear main entrance doors. Chutes at the service doors are inflatable in some versions and non-inflatable in others.

Inflatable chutes can be readied in a few seconds. The chute compartment door is dropped across the entrance, automatically releasing the packaging straps. Two support lines are hooked to each side of the door frame, the chute rolled out, and a handle pulled to release compressed air from a supply cylinder into the chute. Inflation takes only five to eight seconds.

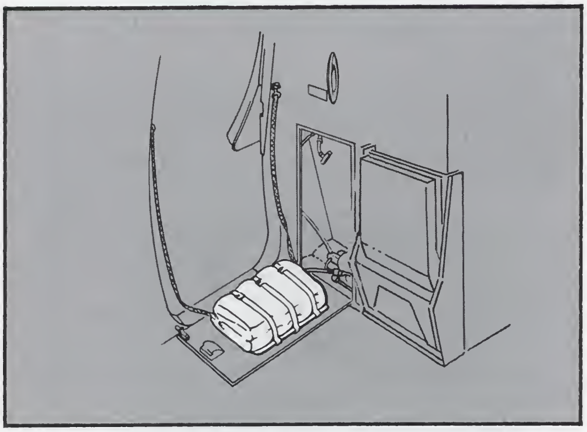
In normal airplane attitudes, chute angle is approximately 30° at the aft entrance and 40° at the forward entrance. Even with nose gear collapsed, chute angle aft is only 43°. Handholds on the chute allow it to be held for use as a slide in event of malfunction of the inflating mechanism. In a water landing, the chute can be quickly detached at the air line and V-blocks, and will support a number of persons by use of flotation handles on each outboard side of the chute.

Non-inflatable slides require that at least two men be available to hold the slide away from the fuselage.

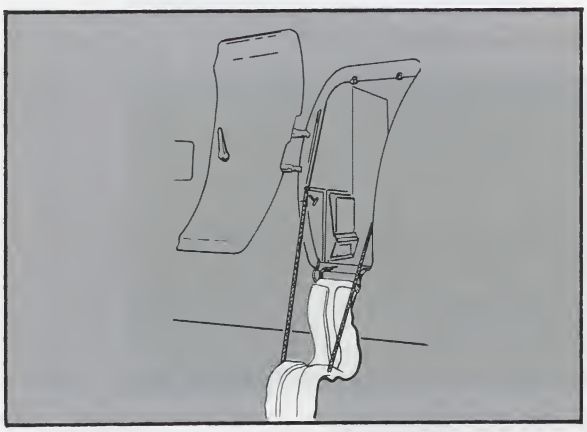
When the overwing emergency escape hatches are removed, a red tape attached to a rope end is exposed in the upper frame, and the rope can be pulled out to aid in climbing down from the wings. Flight compartment escape ropes are in latched compartments over the sliding windows. In some models, another rope is carried in the coat closet forward of the forward entrance, for possible use by crew members in climbing down from the main entrance when passenger loading ramps are not at hand.



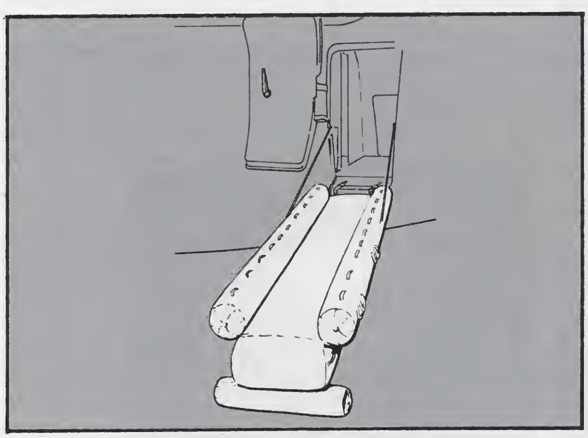
INFLATABLE SLIDE STOWAGE



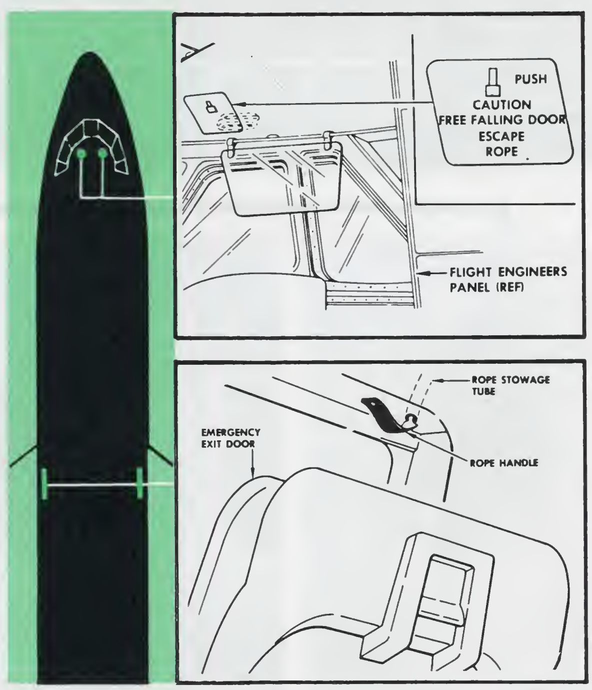
STEP 1: SLIDE IN READY POSITION



STEP 2: IN POSITION FOR INFLATION



STEP 3: SLIDE FULLY INFLATED



ESCAPE ROPE LOCATIONS

"CHOP-THROUGH" AREAS

Should it be necessary to force entry into the cabin, the forward section, between the major splices at the wing root (Sta 640.33) and forward of the forward window (Sta 403.5) will be easiest to chop or saw through. Gage of the aluminum alloy skin is .070 between the floor and the longitudinal splice above the windows, .067 above the splice. There are no stringers from 12 inches above the floor to approximately 42 inches circumferentially from the airplane centerline. Beltframes are 19 inches center-to-center and are of .050 aluminum alloy.

Parallel cuts from just above the window frame, down alongside the beltframes to the first stringer, will make an opening approximately 1½x3 feet, and will not cut through any airplane system lines. The transverse cut may be made above the window and/or above the stringer.

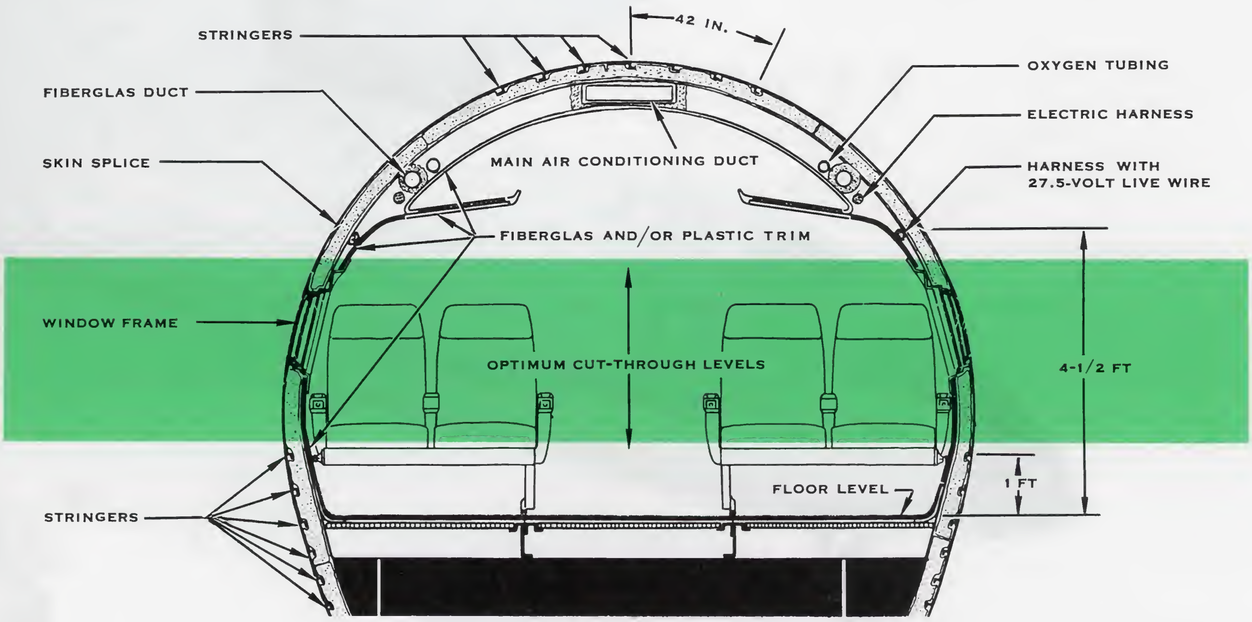
If an opening is made higher than just above the windows, the following points should be noted:

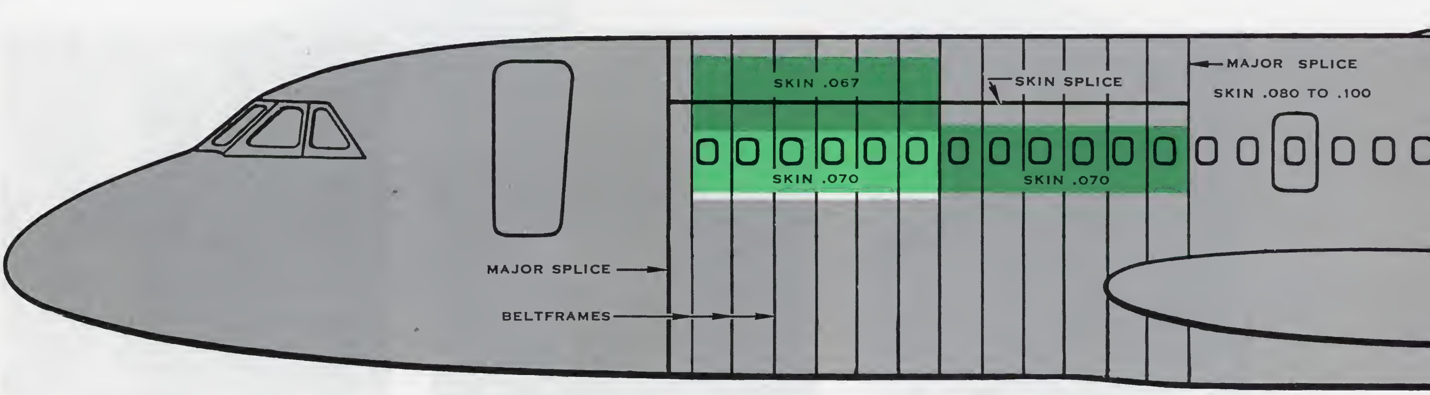
1. Approximately 8 inches above the windows is an electrical harness that will probably contain a 27.5-volt battery-energized "hot" wire. This runs to emergency exit lights and is energized by an inertia switch that trips automatically at 1½ G's, as well as by flight deck or stewardess panel switches. The inertia switch bypasses any flight deck cutoffs and hence cannot be inactivated by the crew.

2. Other wires in this harness, and in another harness higher up, will be energized unless all flight compartment switches have been turned off.

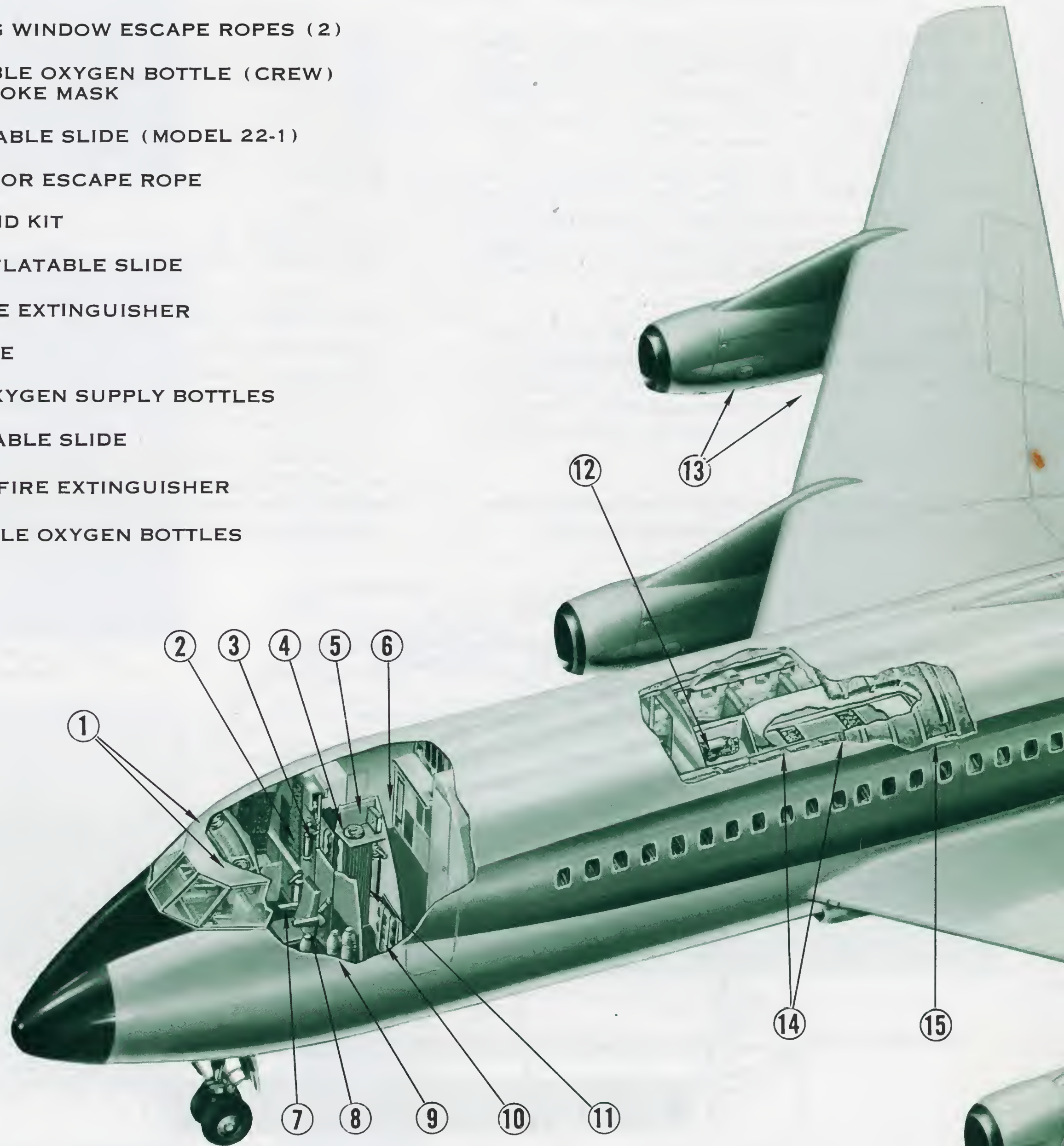
3. Passenger emergency oxygen tubing runs outboard of the hatracks, just inboard of the ventilating air duct. While this tubing would not normally be open to the supply cylinders in the flight compartment, firemen always anticipate in such a case that oxygen may have been turned on.

4. If entry is forced above window level, it should be in the lounge area (forward six windows). Aft of this point, the center rectangular air conditioning duct "Y's" down toward the sides over the hatracks.





1. SLIDING WINDOW ESCAPE ROPES (2)
2. PORTABLE OXYGEN BOTTLE (CREW) AND SMOKE MASK
3. INFLATABLE SLIDE (MODEL 22-1)
4. FWD DOOR ESCAPE ROPE
5. FIRST-AID KIT
6. NON-INFLATABLE SLIDE
7. CO_2 FIRE EXTINGUISHER
8. FIRE AXE
9. MAIN OXYGEN SUPPLY BOTTLES
10. INFLATABLE SLIDE
11. WATER FIRE EXTINGUISHER
12. PORTABLE OXYGEN BOTTLES



NON-INFLATABLE SLIDE STOWAGE

CO_2 FIRE EXTINGUISHER

CREW PORTABLE OXYGEN BOTTLE

EMERGENCY EQUIPMENT LOCATIONS
(TYPICAL)

(13) FIRE DOORS (LH SIDE EACH POD)

(14) PASSENGER OXYGEN OUTLETS (3 OVER EACH SEAT)

(15) EMERGENCY HATCH ESCAPE ROPES (2)

(16) WATER FIRE EXTINGUISHERS (2)

(17) PARACHUTE FLARES

FIRE CAUTION AREAS—
Fuel and Hydraulic Fluid

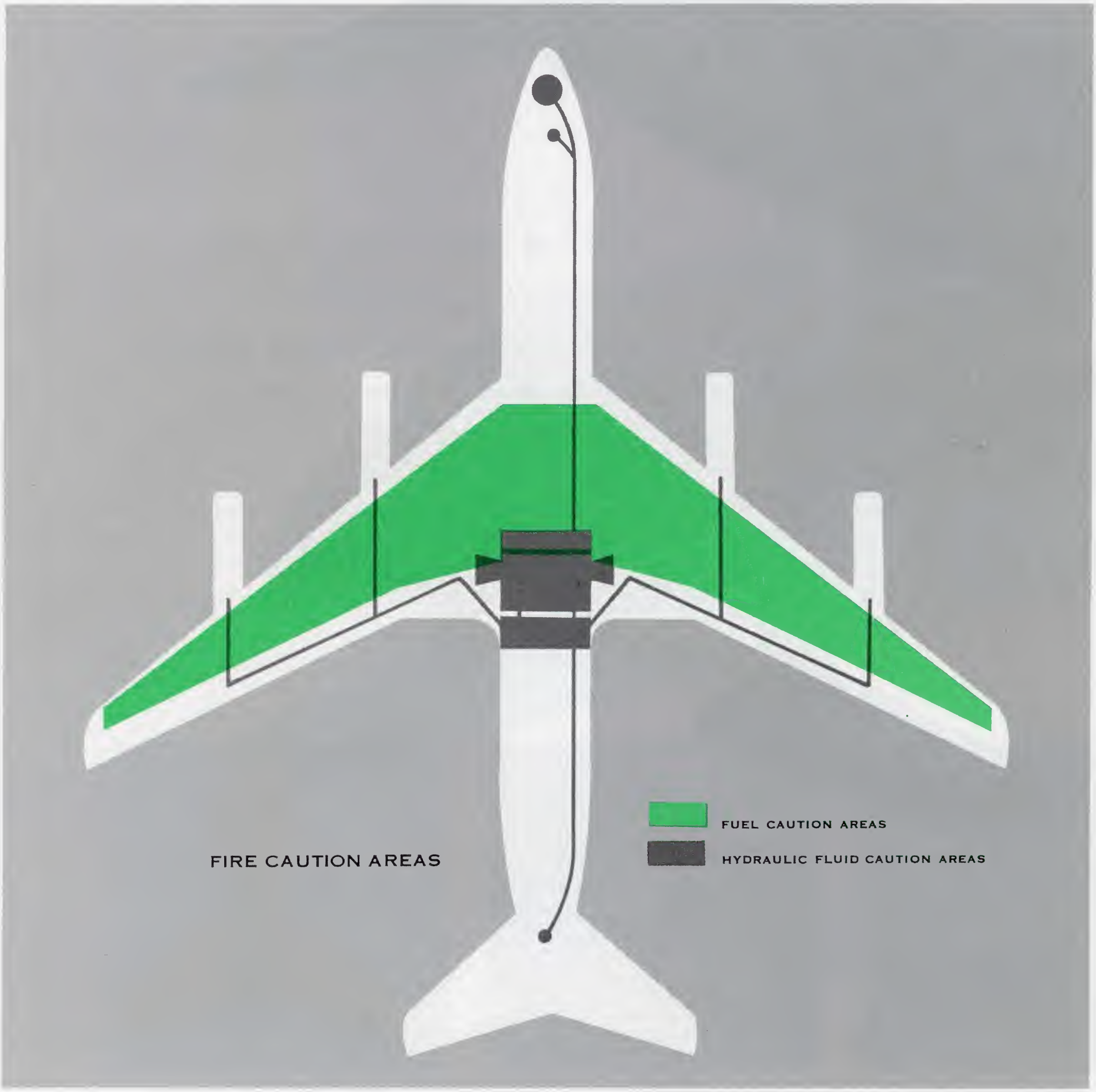
Principal fire danger, as in any airplane, is from fuel. JP-type fuels, while less volatile than gasoline, burn much like gasoline, and firefighting techniques are the same.

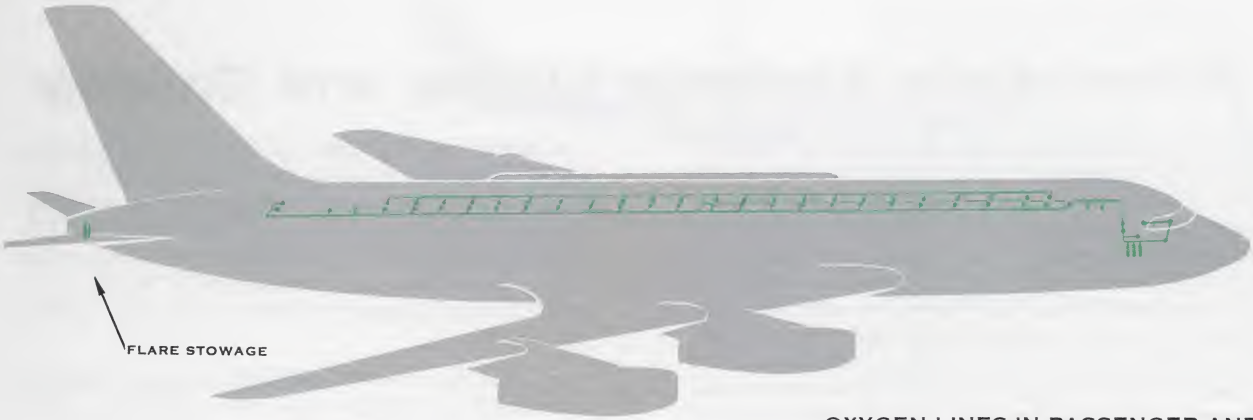
Fuel is stored in the wing and center section cells of the 880M. One fuel line, with no valves or pumps, runs across the fuselage forward of the hydraulic compartment to connect the wing tanks. The area through which the line runs is sealed, like the wing tanks, with provisions for ventilation and drainage.

Second possible fuel for fires is hydraulic fluid. Hydraulic system lines run from the hydraulic compartment forward and aft along the right-hand side of the fuselage beneath the floor, and out through trailing edges of the wings to pylon aft fairings and the spoiler actuators.

Skydrol 500 is fire resistant and will not burn at ordinary temperatures without wicking, but it is not fireproof. Flash point is given by the manufacturer as 360°F; fire point (at which it will burn steadily) as 425°F. At temperatures over 1100°F, particularly in spray form, Skydrol may ignite spontaneously. An overheated brake is, therefore, a fire peril. If hot enough to cause a blowout, hydraulic lines may rupture, and contact of the fluid with the hot brake may cause a localized fire.

MIL-H-5606 (red) fluid, used in struts, truck positioner, and nose gear liquid spring, has a minimum flash point, by the military specification, of 200°F.





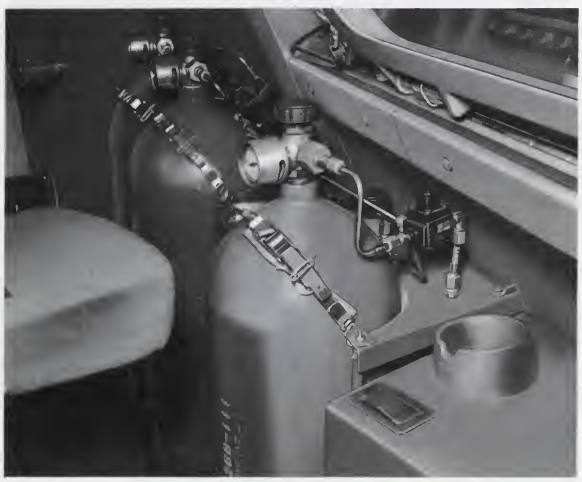
OXYGEN LINES IN PASSENGER AND CREW COMPARTMENTS

CAUTION AREAS — Oxygen and Flares

Main oxygen supply cylinders are retained in a rack on the left-hand flight compartment wall, aft of the pilot. There will normally be no oxygen in the passenger cabin oxygen lines.

In some versions of the "880" (including Model 22-2), parachute flares are carried in release chutes in the tail cone, approximately 34 inches from the aft end of the fuselage.

MAIN OXYGEN SUPPLY BOTTLES

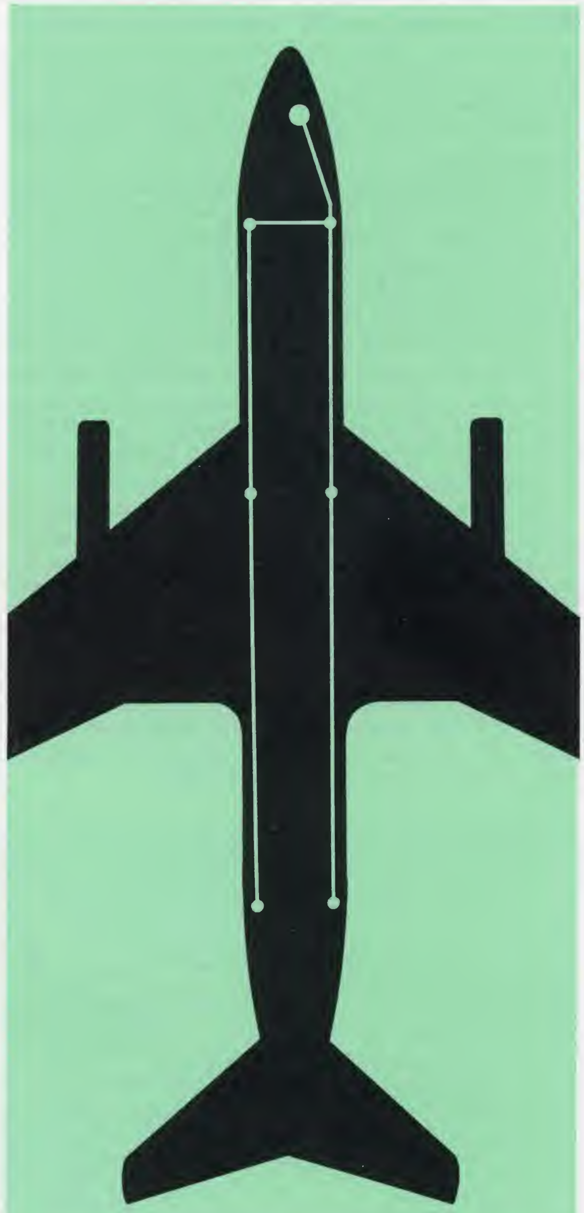


CAUTION AREAS — Electrical

With engines shut down, the only electric power in the airplane is from the 13.5-ampere-hour 27.5-volt battery, located on the aft face of the bulkhead aft of the radome, right-hand side.

If the battery switch on the flight engineer's panel is off, there will be no energized wiring aft of the flight compartment below the floor or in the wings, and none in the cabin except for cabin emergency lights (see page 5).

The battery lead can be disconnected at a quick-disconnect fitting, access to which is via the nose wheel well; or the lead can be cut by entering the right-hand electrical compartment.



EMERGENCY LIGHT WIRING

Emergency Airplane Lifting and Towing

Unusual circumstances, such as an inadvertent overrun of the landing strip, may so position the aircraft that unusual towing conditions may be necessary to return the aircraft to sound runways and normal handling conditions. If the aircraft has come to rest on uneven and/or soft terrain, and under conditions involving mud, water, and snow, the normal towing limitations and precautions, contained in the Maintenance Manual, should be carefully observed to avoid adding to any damage that may already have been incurred. The Maintenance Manual should also be studied if it is necessary to lift, shore, or turn the aircraft into the proper position for towing.

An adequate crew should be provided to man the aircraft and the towing vehicles, and to act as observers to prevent possible damage while the airplane is being towed. The aircraft brakes should be operative and manned so as to preclude the possibility of overrunning the towing lines and equipment, or to otherwise stop unwanted movement of the airplane at any moment.

The towing operation can be facilitated by removing loose and non-essential equipment and as much fuel as possible. In removing equipment to lighten the airplane, center-of-gravity location should be considered so that there is no possibility of the aircraft tipping. It should be borne in mind that the conditions of emergency towing will not be the same as those for normal towing, when uneven and potentially soft underfooting is encountered. Wind conditions should be considered because it is possible that the aircraft may inadvertently tilt to an unusual angle during the towing operation.

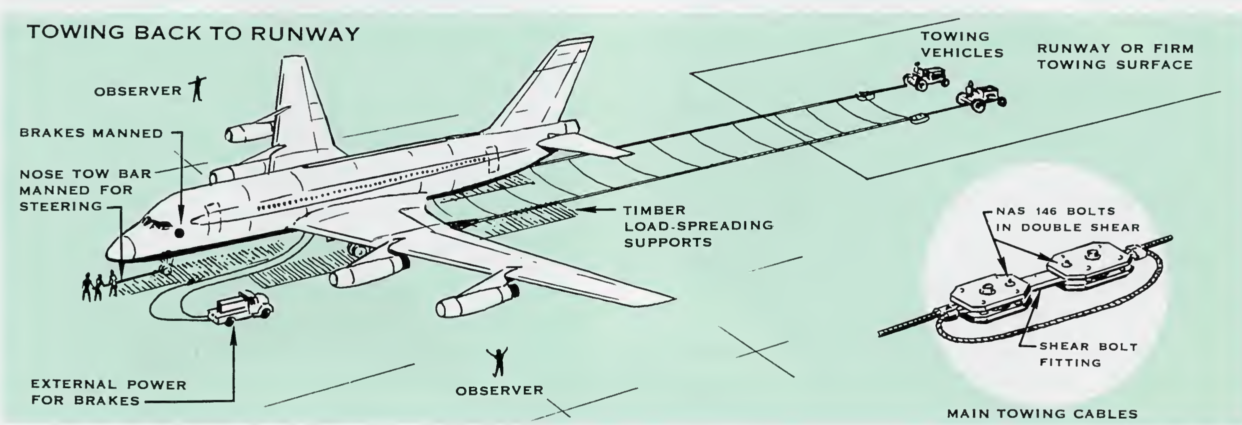
On a hard level runway, towing is accomplished at the nose landing gear. On rough terrain and/or soft ground, in mud, snow, etc, towing should be accomplished only from both main landing gears simultaneously. Front and rear towing lugs are provided on each main landing gear truck, providing for both forward and backward towing. When towing in a backward direction, the nose wheel tow bar should be attached to the nose wheel gear for steering only, and should be manned by several persons for adequate control. Sharp turns should be avoided.

A pair of towing cables of adequate strength and length should be attached to the main landing gear trucks, and extend parallel to the towing vehicles. Towing vehicles should be on a firm towing surface. Using towing cables of equal length will assure towing vehicle operators that the aircraft is being towed parallel to its axis and normal to the main landing gear trucks.

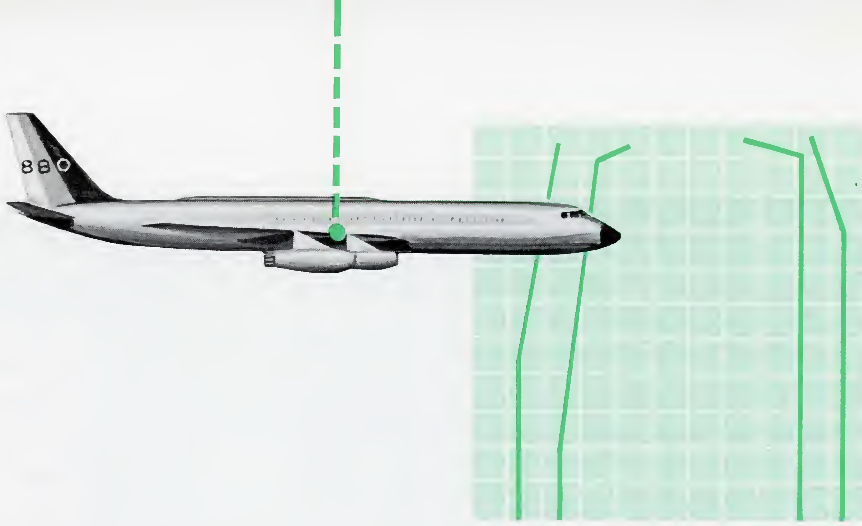
Bridging the two tow cables at frequent intervals, with lengths of manila rope, will restrain the whipping action of the tow cables if they should break or snap free under load, thus precluding damage to aircraft and equipment, or injury to personnel. Each end of both cables should be similarly provided with short lengths of lighter cable attached to the main towing cables, and with some slack at the attachment of the landing gear truck to the towing vehicle. These lighter cables will restrict the main tow cables, if the main attachment points should break free under load.

To preclude direct towing damage to the landing gear structure, each of the main tow-line cables should be rigged with NAS 146 shear bolt fittings. The NAS 146 bolt in double shear in the shear bolt fitting will shear before the main landing gear maximum permissible towing pull (20,800 x 1.26 = 26,200 lb) can be transmitted to the main landing gear trucks. Some slack in the cable, which extends around the shear bolt fittings, will prevent excessive whip if the bolts are sheared in towing.

It is possible that the aircraft may have progressed to its resting position by traversing areas just firm enough to support it while traveling at relatively high speed. If the aircraft is towed back across this same area, the ground may not be sufficiently firm to provide adequate support for the aircraft weight, at the slow towing speed. If any indication of unfirm ground is noted, supporting timbers should be placed under and ahead of the wheels as the aircraft is towed. These should be of sufficient strength to distribute the wheel loading. Under wet or icy conditions, sand or similar material should be applied to the timbers to prevent the tires from slipping.



Weight and Balance



Convair 880

In designing an automobile or an airplane, exact location of the center of gravity must be established. In an automobile, the location is usually of interest to the designer alone; it is a rare motorist who knows where his car's CG is even supposed to be. But in the Convair 880, as in any transport airplane, CG location must be re-established, longitudinally at least, with every major modification to the airframe, re-computed for every flight, and perhaps computed again several times during flight.

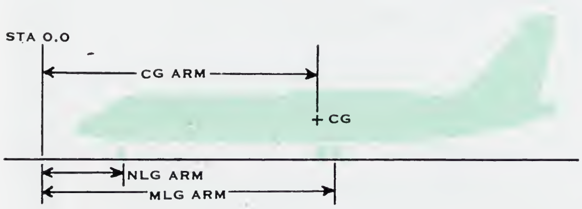
The computation is simple in theory, though the arithmetic can be somewhat lengthy. It is based on one aspect of the principle of moments: the gravitational moment of a body about a certain point is the product of the weight of the body times the horizontal distance of the point from the center of gravity. In the "880," the reference point chosen is Fuselage Station 0.0, which is 100 inches forward of the airplane nose. The moment of the "880" about this point is then the airplane weight times the CG station.

With the "880" supported on its landing gear and leveled longitudinally, the airplane moment about Sta 0.0 is also the sum of the moments produced by the weight on the nose gear and the weight on the main gears; that is,

$$\text{CG Sta} \times \text{airplane wt} = (\text{NLG Sta} \times \text{NLG wt}) + (\text{MLG Sta} \times \text{MLG wt});$$

therefore;

$$\text{CG Sta} = \frac{(\text{NLG Sta} \times \text{NLG wt.}) + (\text{MLG Sta} \times \text{MLG wt})}{\text{NLG wt} + \text{MLG wt}}$$



Shortly before an "880" goes into service, CG location is determined by this formula, by actually leveling and weighing the airplane on platform scales, or by use of electronic weighing pads on airplane jacks. Thereafter, a permanent log is kept of all modifications or changes of equipment that affect balance, and the CG station is revised accordingly.

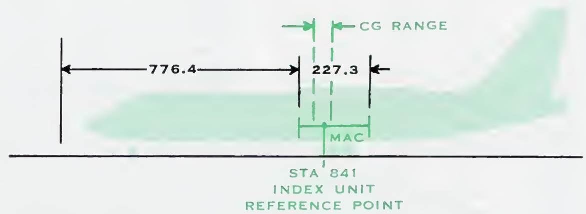
The basic airplane weight, as defined by Civil Air Regulations No. 40, is termed Certified Weight Empty. It might be described as the status of an airplane ready to be loaded for commercial service; it includes all permanently installed equipment, together with undrainable engine oil and unusable fuel, but without "standard operating items." This weight in the "880" is usually 83,000 to 85,000 pounds.

Standard Operating Items are defined as crew and crew baggage; drainable and usable engine oil; passenger service (pillows, blankets, towels, etc.); buffet contents; and water. When these items — usually approximately 2000 pounds — are added to Certified Weight Empty, the airplane is at Basic Operating Weight; that is, ready for fuel, cargo, and passengers.

Basic Operating Weight is the figure with which the ground loading and flight crews will begin. It represents a weight and moment that should vary little from day to day. Passengers, cargo, and fuel are variable factors on each flight. Passenger and cargo, added to basic operating weight, give Zero Fuel Weight. To this is added the fuel load for Ramp Gross Weight, which, less approximately 500 pounds for fuel consumption on the ground, will be the Takeoff Weight.

For flight purposes, CG location is expressed in percent of the mean aerodynamic chord, which, in effect, establishes a relationship between CG and wing center of lift. Since the mean aerodynamic chord of an "880" is 227.3 inches, extending aft from Sta 776.4,

$$\text{CG in \% MAC} = \frac{\text{CG Sta} - 776.4}{227.3} \times 100$$



This percentage must be computed for two purposes: airplane balance limitations are expressed in terms of percent MAC, and so also is the setting for takeoff stabilizer trim. Flight limits are from 16.5% to 34%, varying with gross weight and speed. Stabilizer trim for takeoff will be 6° airplane-nose-up with a forward CG, 4° with a midship CG, and 2° with an aft CG.

Of particular interest is the fact that the "880" will always be within established design limits if the zero

fuel CG is within certain designated limits, and if specified fuel fill and usage sequence is followed. The loading schedule is of first importance; if this is properly managed, takeoff requirements will be met by merely following standard fueling procedure.

The Weight and Balance Manual prepared for each version of the "880" lists the "arm" — distance to Sta 0 — of each crew member and passenger, each cargo compartment center, and all standard operating items. Using the manual and individual airplane records, it is possible to compute the zero fuel CG station to within one hundredth of an inch. This is rarely necessary, and it would involve quite a few figures; the moment of a cup of coffee at the aft buffet is several hundred inch-pounds, and a 130-pound stewardess at her aft station "weighs in" at 165,490 inch-pounds moment.

There are several standard approaches to bring such figures down to more manageable size. Graphs can be used; blocks of passenger seats, or frequently used fuel loads, can be assigned an average moment; for many computations, inch-pounds can be expressed in larger units. Tables can be prepared for recurrent balance problems, enabling the loader to bypass actual computing of moments. All these methods are available and are made use of in the "880" Weight and Balance Manual.

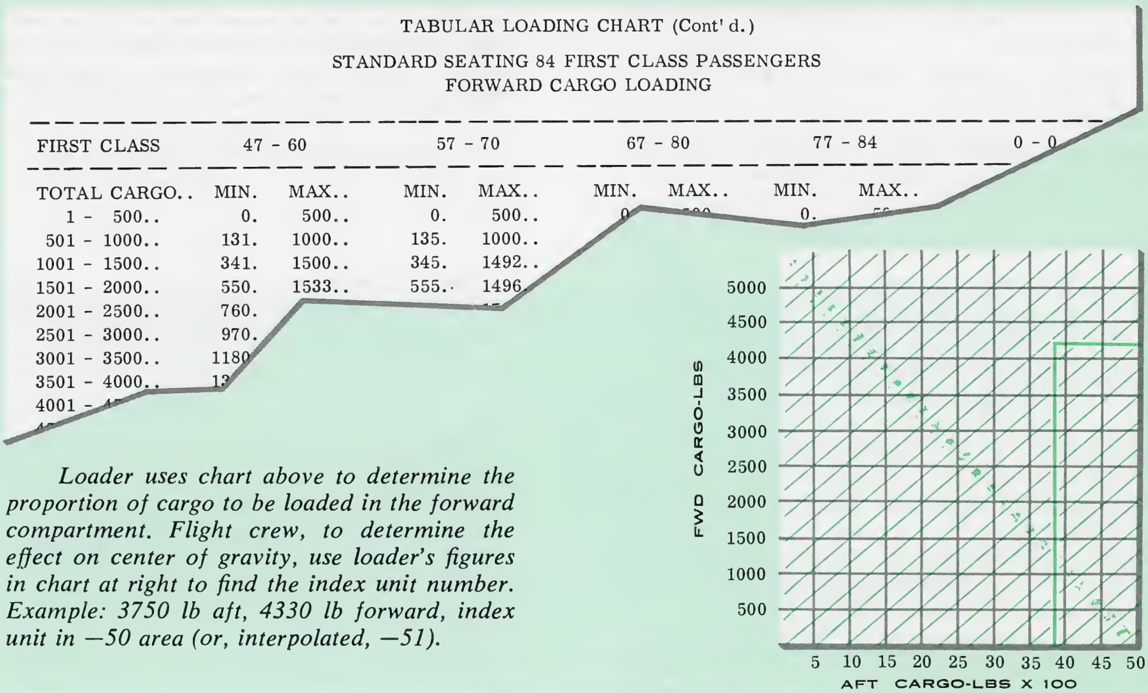
Cargo loadings in forward and aft compartments are used to control airplane balance. The manual provides tables for tabular loading control. Passenger loading is assumed to follow the usual pattern of window seats occupied first, aisle seats next, and center seats (in three abreast seating) last. When the number of passengers and the cargo tonnage are known, the table gives the proportion of cargo to be loaded forward.

Under the column headings for number of passengers will be found maximum and minimum cargo weight to be loaded in the forward compartment. The maxima and minima take into account the most adverse conditions — whether seats are filled front to back or vice versa, for example, or if there is uneven distribution of buffet contents. With the cargo properly distributed, and the total zero fuel weight within maximum limits, the only concern left is to be sure the fueling procedure is normal.

Normal, in this case, means that distribution is maintained approximately equal between outboard and inboard wing tanks until the outboard tanks are full. It is anticipated that the two tanks will often be filled simultaneously with pressure fueling. The only restriction in fueling is not to fill outboard tanks full with the inboard empty. Outboard tanks are considerably aft of CG. Additional adverse factors, such as maintenance personnel all in the rear, could conceivably cause a "tail tipdown." It is immaterial whether one wing is filled before the other; the temporary lateral imbalance need cause no concern.

Even for takeoff, it is not absolutely necessary that fuel quantity be equal between outboard and inboard tanks — only that the CG be within limits. With a full fuel load, there will always be an excess inboard because each inboard tank holds approximately 4000 lb more fuel than the outboard tank. The Weight and Balance Manual contains permissible distribution curves for both takeoff and landing. If fuel loading is found to be uneven, these curves can be consulted to

TABULAR CARGO LOADING CHART



Loader uses chart above to determine the proportion of cargo to be loaded in the forward compartment. Flight crew, to determine the effect on center of gravity, use loader's figures in chart at right to find the index unit number. Example: 3750 lb aft, 4330 lb forward, index unit in —50 area (or, interpolated, —51).

DETERMINATION OF PERCENT MAC AND TAKEOFF STABILIZER TRIM

LOADING FORM

	WEIGHT	INDEX UNITS
WEIGHT EMPTY		
STANDARD OPERATING ITEMS		
CARGO (FWD.) (AFT)		
PASSENGERS (FWD.) (AFT)		
ZERO FUEL WEIGHT		

FUEL	WEIGHT	INDEX		
1 & 4 MAIN				
1 & 4 REPLENISH				
2 & 3 MAINS				
2 & 3 REPLENISH				
TOTAL				
RAMP CONDITION				
LESS TRIP FUEL				
LANDING CONDITION				

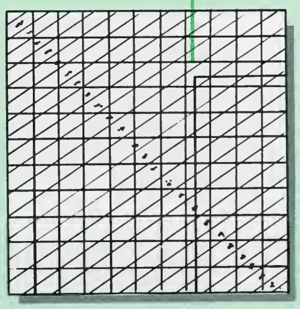
PER CENT M.A.C. ______ STABILIZER TRIM SETTING ______

Loading form has column for weight and one for index units.

Weight Empty and Standard Operating Items are taken from airplane Weight and Balance Report.

Cargo weight and index are from cargo loading sheets.

	WT	INDEX
PASSENGERS (FWD ___) (AFT ___)	______	______

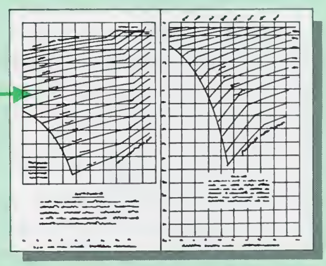


Index units for passengers are obtained from graph.

FUEL	WT	INDEX
1 & 4 MAIN	______	______
1 & 4 REPLENISH	______	______
2 & 3 MAIN	______	______
2 & 3 REPLENISH	______	______

LOADING (Cont' d.)

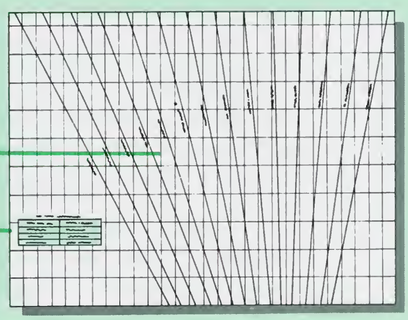
GALLONS	WEIGHT	INBOARD MAIN ARM	INBOARD MAIN INDEX	INBOARD REPL. ARM	INBOARD REPL. INDEX	OUTBOARD MAIN ARM	OUTBOARD MAIN INDEX	OUTBOARD REPL. ARM	OUTBOARD REPL. INDEX
75	500	780.0	- 3.1	711.4	- 6.5	849.0	0.4	980.0	7.0
149	1000	782.2	- 5.9	712.5	- 12.9	848.9	0.8	989.2	14.8
224	1500	784.0	- 8.6	713.5	- 19.1	849.0	1.2	993.5	23.2
299	2000	785.6	- 11.1	714.4	[illegible]	849.1	1.6	1000.2	31.8
373	2500	787.2	- 13	715.[illegible]		[illegible]	[illegible]	1003.[illegible]	
448	3000	788.5							
522	3500	789.8							
597	4000	791							
672	4500	7[illegible]							
746	5000								
55[illegible]									



Indexes are obtained from table. Inboard-Outboard distribution is checked against permissible distribution curves (right).

PERCENT MAC ______

STABILIZER TRIM SETTING ______



Plus and minus index units are added algebraically, and percent MAC is determined from graph. Stabilizer trim setting is given in table at left.

ascertain if distribution is within limits. For en route flight, the Flight Manual recommends that engines be crossfed after takeoff until the load is equalized between inboard and outboard tanks, and that fuel be used equally from all tanks thereafter.

For landing, the recommendation is that fuel remaining in inboard replenishing tanks, which are forward of the CG, should be transferred aft to the main tanks. Should transfer not be possible, more fuel should be held outboard to compensate for the forward moment of the inboard replenish tanks. The permissible distribution curves take account of this possibility.

In computing CG in percent MAC for takeoff stabilizer trim setting, the manual makes use of an index system. The index numbers represent, in effect, moments in 10,000-inch-pound increments, related to an arbitrarily chosen CG reference point (Sta 841):

$$\text{Index Unit} = \frac{\text{Weight} \times (\text{Balance Arm} - 841)}{10{,}000}$$

Tables are used for assigning index numbers to passenger and cargo loads with reference to the portion loaded forward of Sta 841, and to fuel in 500-lb increments to each tank. Forward indexes are minus; aft indexes, plus. These indexes are added algebraically, and CG in percent MAC is determined quickly from a graph.

Leveling and Weighing

Since airplane empty-weight center of gravity may be safely assumed to be on the fuselage centerline, the chief concern in leveling the airplane is to see that the waterline is level longitudinally. There are, literally, half a dozen means provided for telling when an "880" is level. Two require use of an engineer's transit or sight level, two use a spirit level, one a plumb bob, and the other a 50-foot water hose, preferably with transparent end sections.

A row of six brazier-type rivet heads on each side of the fuselage — the only protruding rivets on the "880" skin, incidentally — mark WL 68 at Stations 155.75, 636.75, 650, 916.25, 930, and 1420. Using the transit is much easier if a 6-foot scale is held up against the rivet, and readings taken from the scale, rather than by sighting in directly on the rivets themselves.

On the lower external longeron, or keel, a pair of small drill-mark indentations have been made at WL -2 at Stations 603 and 1036. These can be sighted on directly with a transit.

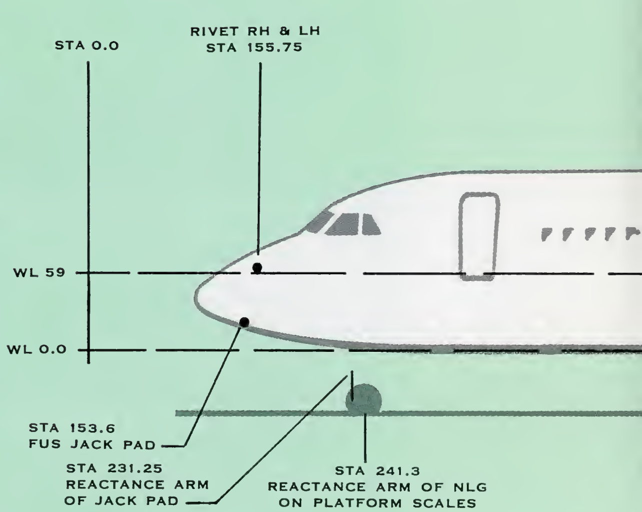
At Sta 748.8 inside the cabin, an eyebolt has been installed at the top of the fuselage and an indicator on the top surface of the center floor beam. By suspending a plumb bob from the eyebolt, the airplane can be leveled both longitudinally and laterally. An overhead trim panel must be removed, however, and a floor panel taken up to obtain access to this installation.

A 24-inch spirit level may be used on leveling lugs installed in the main wheel well, on the forward bulkhead, and on the left face of the center bulkhead, for lateral and longitudinal leveling. The level may also be held up against the external longeron anywhere between Sta 678 and Sta 832. Between these two points, the longeron lower surface has a constant slope of 0.005 inch per inch; therefore, a spacer 0.100 thick must be used at the forward end of a 20-inch level, or a 0.120-inch spacer with a 24-inch level.

The water hose method can be adapted for "880" use in connection with the drill-marks in the external longeron. A hose is filled with water, and the water levels at the ends of the hose are matched with the drill-marks. Homespun as this method appears, it is highly regarded by Convair engineers. Since the drill-marks are approximately 36 feet apart, the accuracy possible is considerably higher than that with a spirit level; and a water hose is often easier to come by than a transit.

For a comparison indicating possible accuracies of the various methods, it may be noted that the maxi-

LEVELING AND WEIGHING DATA



mum error permissible in leveling is 0.1% MAC. This represents:

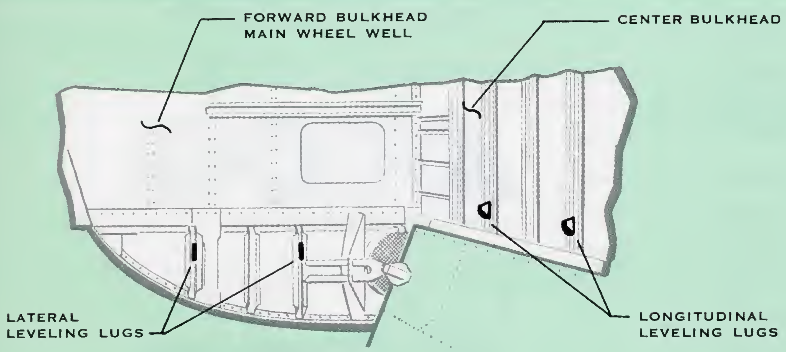
0° 9′ of waterline angle
3.3 inches between fore and aft rivets at WL 68 (transit method)
0.23 inch at plumb bob zero mark
0.05 inch at one end of a 20-inch spirit level
1.1 inches between longeron drill-marks (transit or water hose method)

If the "880" is on a level surface with tires inflated normally, and struts deflated, the waterline will be approximately level. It may be seen, therefore, that longitudinal alignment can be adjusted adequately by inflating or deflating the nose strut. This requires only a supply source of compressed air, and can be done after the airplane is on platform scales or on landing gear jacks.

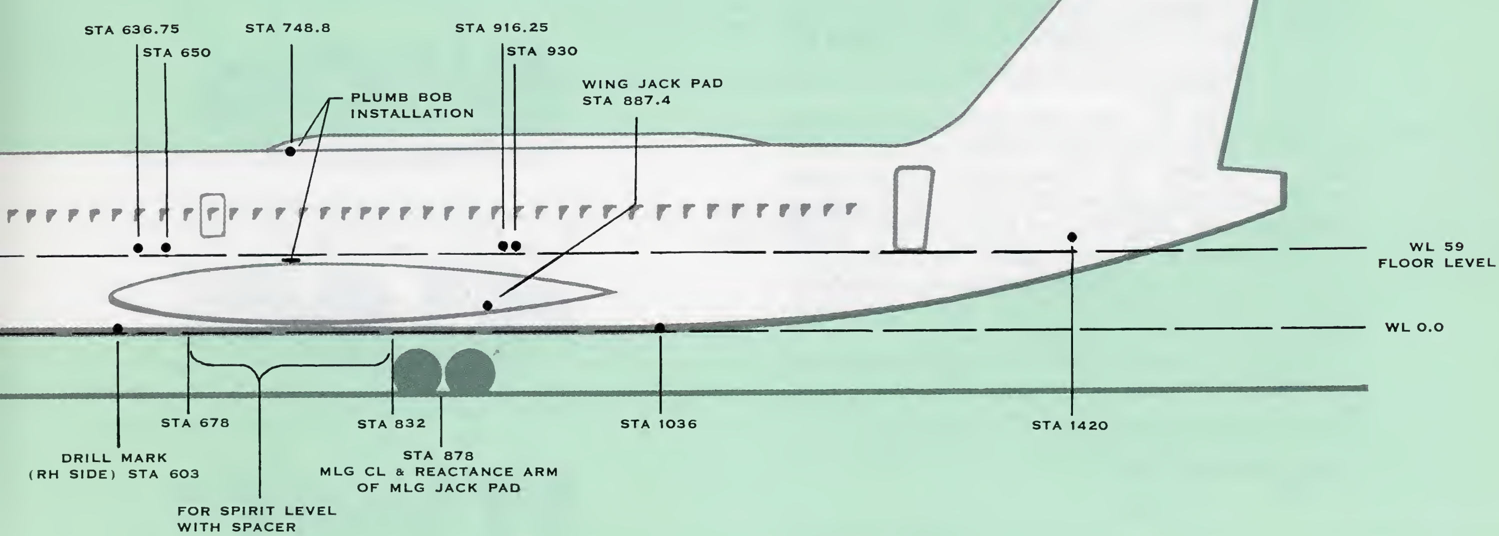
A platform scale under the nose gear should have an area 30 inches wide by 20 inches long and, under each main gear, 40 inches wide by 80 inches long. If the airplane is to be weighed fully loaded (185,000 maximum), scale capacities should be 20,000 pounds for the nose gear and 100,000 pounds for each main gear. Jack pad permissible loads are 15,000 lb on the nose gear and 86,700 lb at each main gear; this will usually permit weighing at ramp weight, though perhaps not at maximum gross.

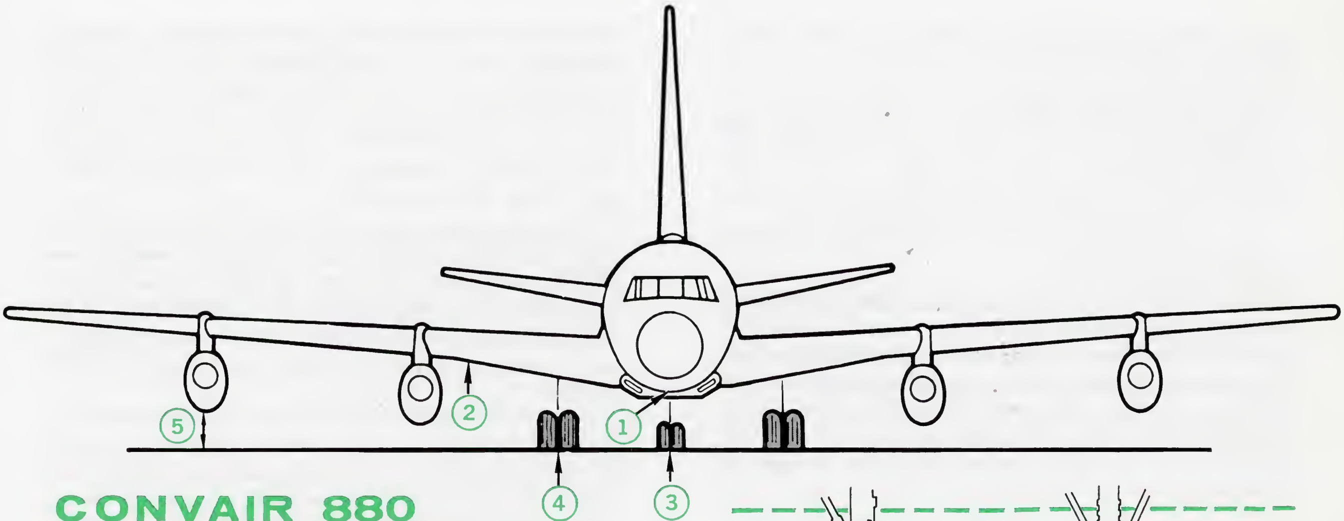
If weighing pads are to be used with fuselage and wing jack pad fittings, the maximum weights are 12,000 pounds forward and 66,400 pounds at the wing pads. It is evident that the airplane cannot be weighed at full ramp weight by use of wing jacks; it can be weighed at maximum landing weight (132,800 pounds).

It is sometimes desirable to lower the airplane overhead clearance by raising the nose to lower the vertical fin tip. If the CG is within zero fuel limits and if outboard replenish tank fuel weight is balanced by an equal amount in the inboard replenish tank, the "880" nose wheel can be raised 36 inches without danger of tail tip-down.



MAIN WHEEL WELL, LH SIDE





CONVAIR 880 PRINCIPAL AIRPLANE CLEARANCES

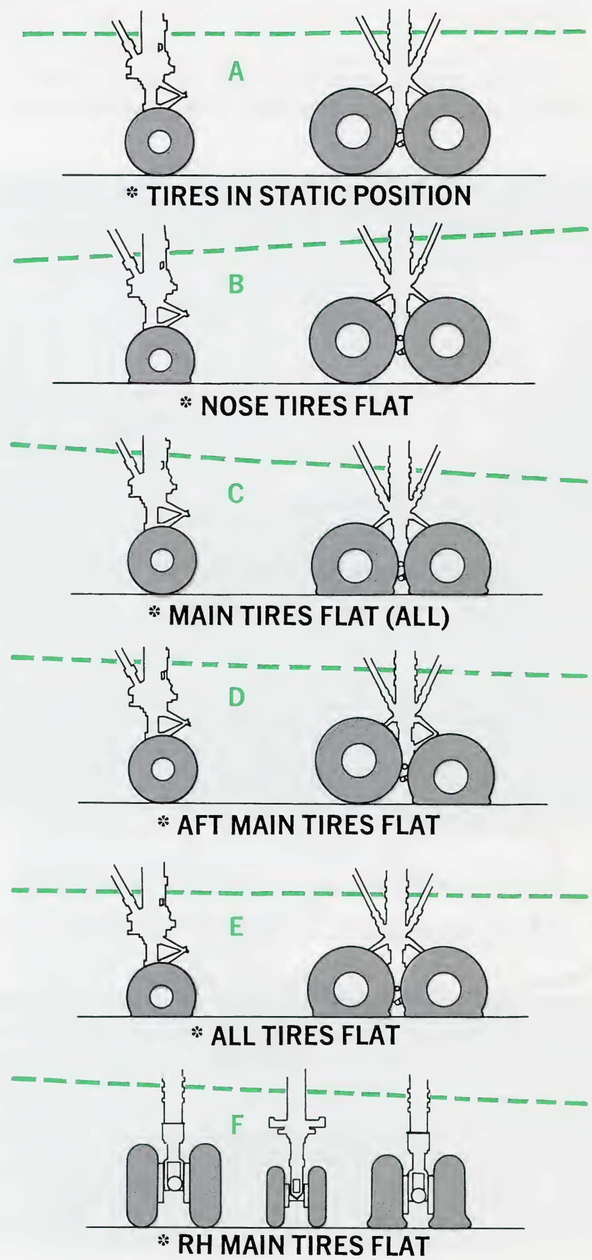
To raise the Convair 880 entirely off the ground, three airplane structure jack points are used: the fuselage (nose) jack point at bulkhead station 153.6, just aft of the radome; and one jack point on each wing at wing station 224.7, four inches aft of the rear spar at fuselage station 887.4.

In addition to the structure jack points, there are jacking provisions at each of the three landing gears to enable the wheels or gear to be lifted individually for servicing. These provisions include three integral jacking lugs under each main gear axle beam (one under each axle and one under the strut) and one jacking lug under the nose gear strut. By raising the front or rear of the main gear trucks, the corresponding wheels, tires, and brakes can be serviced.

All three structure jack points should be raised simultaneously to keep the airplane level and to prevent overloading caused by side loads. The overall weight of the airplane should not exceed the jacking weight of 132,800 pounds when utilizing structure jack points.

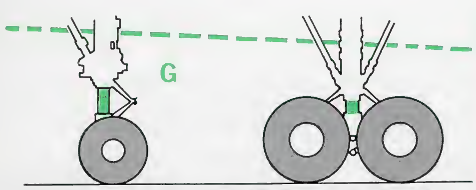
When using the gear jack points, the airplane should be raised only high enough for the tires to clear the ground. As a precaution against inadvertent retracting, down-lock safety pins should be installed in the drag brace of the nose gear and in the side braces of the main gear. The landing gear strut jack points, located at fuselage stations 231.3 and 878 may be used to lift the "880" at a maximum gross weight of 185,000 pounds.

The accompanying chart and illustrations present the limitations and critical distances to take into account when raising or lowering the "880" to clear hangar overheads, etc., and to clear snow banks and obstructions.

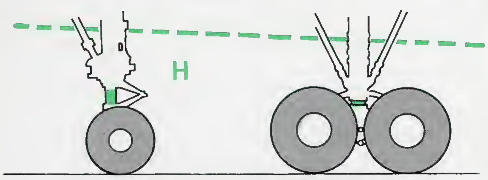


* ALL STRUTS NORMAL
‡ ALL TIRES INFLATED

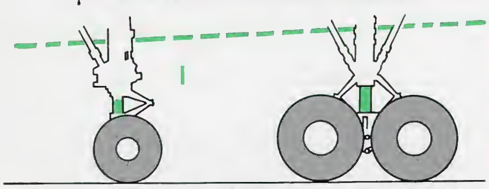
1 NOSE JACK POINT
2 WING JACK POINT
3 NOSE GEAR JACK POINT
4 MAIN GEAR JACK POINT
5 OUTB'D POD CLEARANCE
6 EMPENNAGE CLEARANCE



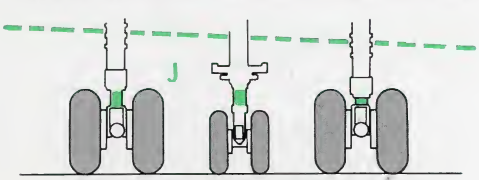
‡ NOSE STRUT INFLATED (EXTREME)



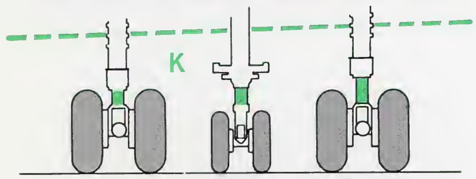
‡ MAIN STRUTS BOTTOMED



‡ MAIN STRUTS INFLATED (EXTREME



‡ RH MAIN STRUT BOTTOMED



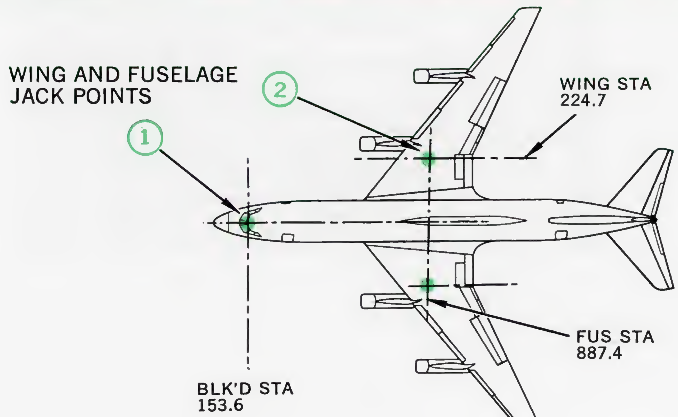
‡ RH MAIN STRUT EXTENDED

CLEARANCES IN INCHES

	1	2		3	4		5		6
		LH	RH		STRUT	AXLE	LH	RH	
A	70.40	99.55	99.55	13.90	11.63	FORE 12.53 AFT 11.90	43.50	43.50	442.80
B	68.47	99.55	99.55	12.20	11.63	FORE 12.53 AFT 11.90	43.50	43.50	444.71
C	71.02	91.25	91.25	13.90	7.10	FORE 8.00 AFT 7.38	38.97	38.97	437.69
D	70.73	93.37	93.37	13.90	9.22	FORE 12.56 AFT 7.80	41.09	41.09	440.10
E	69.09	91.25	91.25	12.20	7.10	FORE 8.00 AFT 7.38	38.97	38.97	435.08
F	70.71	101.78	92.79	13.90	7.10	FORE 8.00 AFT 7.38	51.15	31.32	440.25
G	77.70	99.46	99.46	13.90	11.63	FORE 12.53 AFT 11.90	43.50	43.50	435.60
H	72.10	87.00	87.00	13.90	11.63	FORE 12.53 AFT 11.90	31.20	31.20	416.60
I	69.90	103.30	103.30	13.90	11.63	FORE 12.53 AFT 11.90	47.20	47.20	450.70
J	71.30	105.60	81.20	13.90	11.63	FORE 12.59 AFT 11.90	64.20	10.50	429.70
K	70.10	97.70	105.10	13.90	11.63	FORE 12.53 AFT 11.90	37.30	53.40	446.60

Difference between inflated and deflated nose gear tire is 1.70 inches.
Difference between inflated and deflated main gear tire is 4.53 inches.
Difference between compressed and bottomed nose gear strut is 6.60 inches.
Difference between compressed and bottomed main gear strut is 12.30 inches.
Difference between fully extended and bottomed nose gear strut is 13.00 inches.
Difference between fully extended and bottomed main gear strut is 16.00 inches.

CLEARANCES FIGURED AT JACKING WEIGHT OF 132,800 lb.



INDEX